FREE INSIDE! PICTORIAL SALUTE TO NASA'S 30TH ANNIVERSARY

SHUTTLE SCHEDULE UPDATE

FINAL FRONTIER

The Magazine of Space Exploration

October 1988 USA $2.95/OTHER $3.95

ZERO-G

THE UNBEARABLE LIGHTNESS OF BEING

★ EXCLUSIVE CANDIDATE PREVIEW

BUSH AND DUKAKIS DUKE IT OUT IN SPACE

WHAT HAPPENED TO KENNEDY'S SPACE PROGRAM

PULITZER WINNER MCDOUGALL ON SPACE POLICY

ANTI-MATTER ROCKETS

ASTRONAUT ALUMNI: WHERE ARE THEY NOW?

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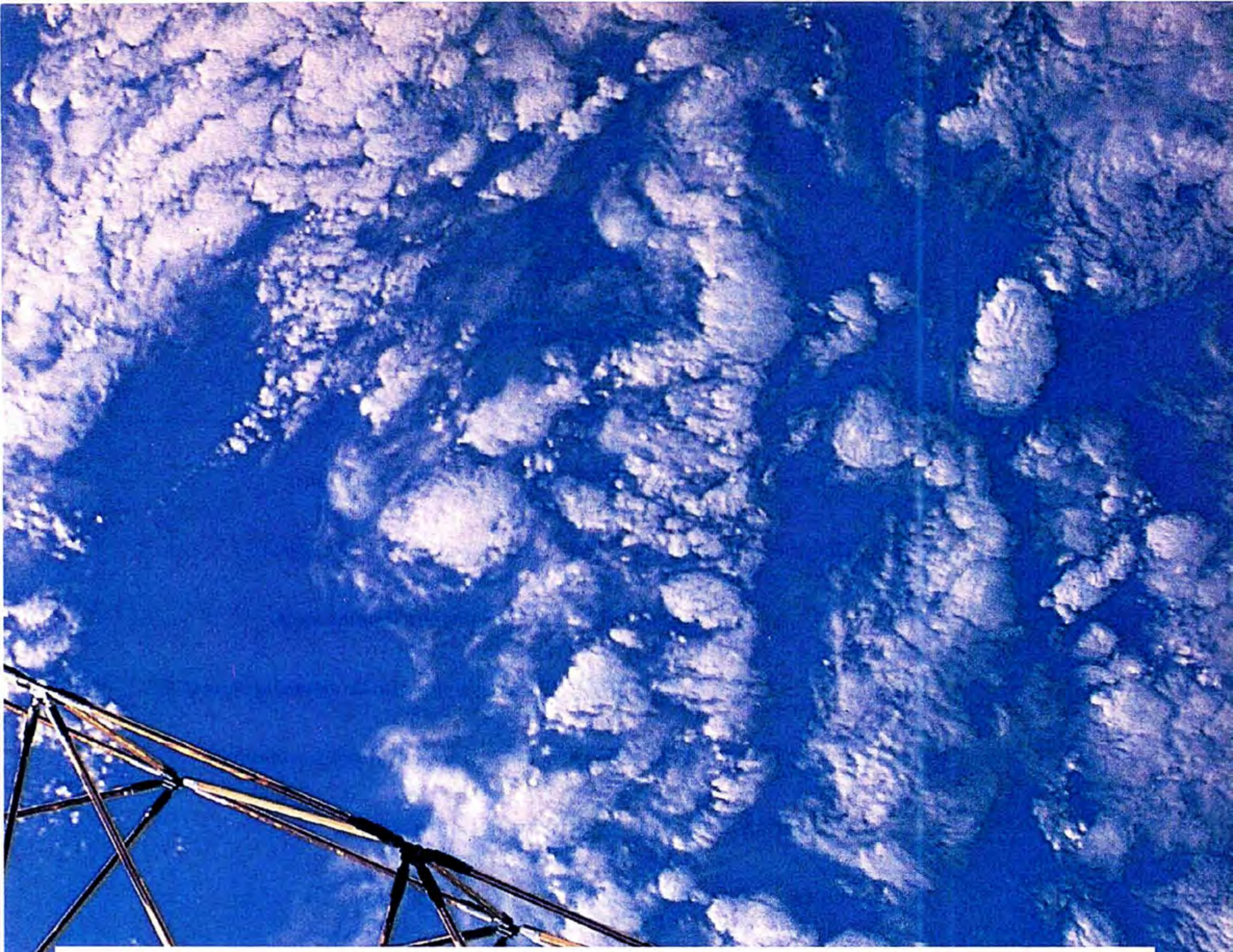

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September/October 1988
Volume 1, Number 4

Astronauts like Gemini 4's Ed White have known about the wonders of floating in zero-gravity for years. We thought we'd give it a try for ourselves. *See page 23.*

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TDRSS
Workhorse today . . .
. . . workforce tomorrow
NASA's Tracking and Data Relay Satellite System (TDRSS) will replace its remote ground tracking stations cost effectively. The first satellite is celebrating five years in space by relaying communication data between NASA's orbiting spacecraft and earth. Each week, day in and day out, the system supports between 400 and 500 unmanned satellite events—with over 98% availability.
TDRSS delivered the same kind of performance as the communication link for all 16 shuttle flights so far. A TRW-built TDRS will be the important first payload when shuttle returns to service. A second TDRS launch follows closely. By the mid-1990 s, a TDRSS constellation will be the cornerstone of the massive space station information system, a national communications conduit into the 21st century.
TRW
TRW Space & Technology Group
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FROM THE PUBLISHER

Never trust anyone over 30
–'60's catch phrase

In October, NASA turns 30. Just like my friends and I, the space agency was conceived at the end of the baby boom. We all grew up together.

Looking back, it seems NASA was the perfect child of the era: one part 50's idealism, one part McCarthyism–with Sputnik sputtering around the cosmos, there was no telling where communism would expand to in this expanding universe.

The twin heads of fear and idealism are still with us: we've got Star Wars and (if all goes off as planned) we've got the launch of Discovery. Still, something's missing.

To me, what's missing is the populism that came with Camelot. When Kennedy and his court tilted their lances at the romantic ideal, the mission suddenly became a common cause. People voted space.

Then came Dallas. After Kennedy, the high level commitment never seemed quite as strong.

Final Frontier is here, of course, to bring it back. In fact, our fourth issue has more space devoted to the cause than any previous one–we've been calling this the political issue around the office.

We've got Bush and Dukakis talking about their plans for the space program. We've got Pulitzer Prize winner Walter McDougall telescoping the political history of the space program into one incisive article.

And as the magazine goes to press, we look forward to the planned launch of Discovery. We'll be there, covering the blast off like nobody else.

If all goes off as planned, we'll soon be writing about the triumphs of shuttle-launched spacecraft: Galileo probing Jupiter's swirling clouds; Magellan speeding toward Venus; the Hubble telescope extending our vision into deep space.

Can we expect any more from a 30 year-old like NASA? I think so. No, I'm not blaming the space agency. I'm just saying that the possibilities are (of course) infinite.

Now that we baby boomers have passed the appointed year, maybe it's time that we got more involved. We could write a letter to our favorite congressman, say.

But we'll have to do something. Being over 30 is quite a responsibility. We'll have to show our kids we can be trusted.

Ever upward,

William Rooney

William Rooney
Publisher

FINAL FRONTIER

THE MAGAZINE OF SPACE EXPLORATION

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LETTERS

TOM R. GARRETT

Pace-Setters

The very nice article on the Mars Balloon concept in the August 1988 issue omitted completely the efforts of an *ad hoc* group to develop an American role in the novel project. NASA may have lost interest, but a team of us at the Planetary Society, California Institute of Technology, Utah State University, Titan Systems, Inc. and Ball Aerospace, with cooperation from the Jet Propulsion Laboratory, designed balloon payloads, conducted test flights and studied a sample payload for the Mars Balloon. The Planetary Society led presentations of this work to Soviet and French space officials and has been asked by them to continue the efforts this year.

We hope we are pace-setters for a NASA role in Mars exploration by balloon. In any case, we will keep advancing the concept.

Louis Friedman
Executive Director
The Planetary Society

Fanfare for the Common Man

Frankly I am awed by the lack of vision and the narrow point of view of Wally Schirra in "Send Only the Best" ("The Observatory," August 1988).

Although exploring space is and always will be a matter of risk, it is only logical to assume that the human race will eventually have to vacate the Earth to survive as a species.

Granted, the trained pilots, engineers and scientists will get us there, but it will take people from all fields and walks of life to start and sustain any long range endeavor in space. When it comes down to it, the elite get nowhere without the support and the imagination of the common man.

I appreciate Mr. Schirra's concern for my well-being, but if given the opportunity, I would be the first to join him on the next adventure into the unknown.

Tom Isabella, Jr.
Flemington, West Virginia

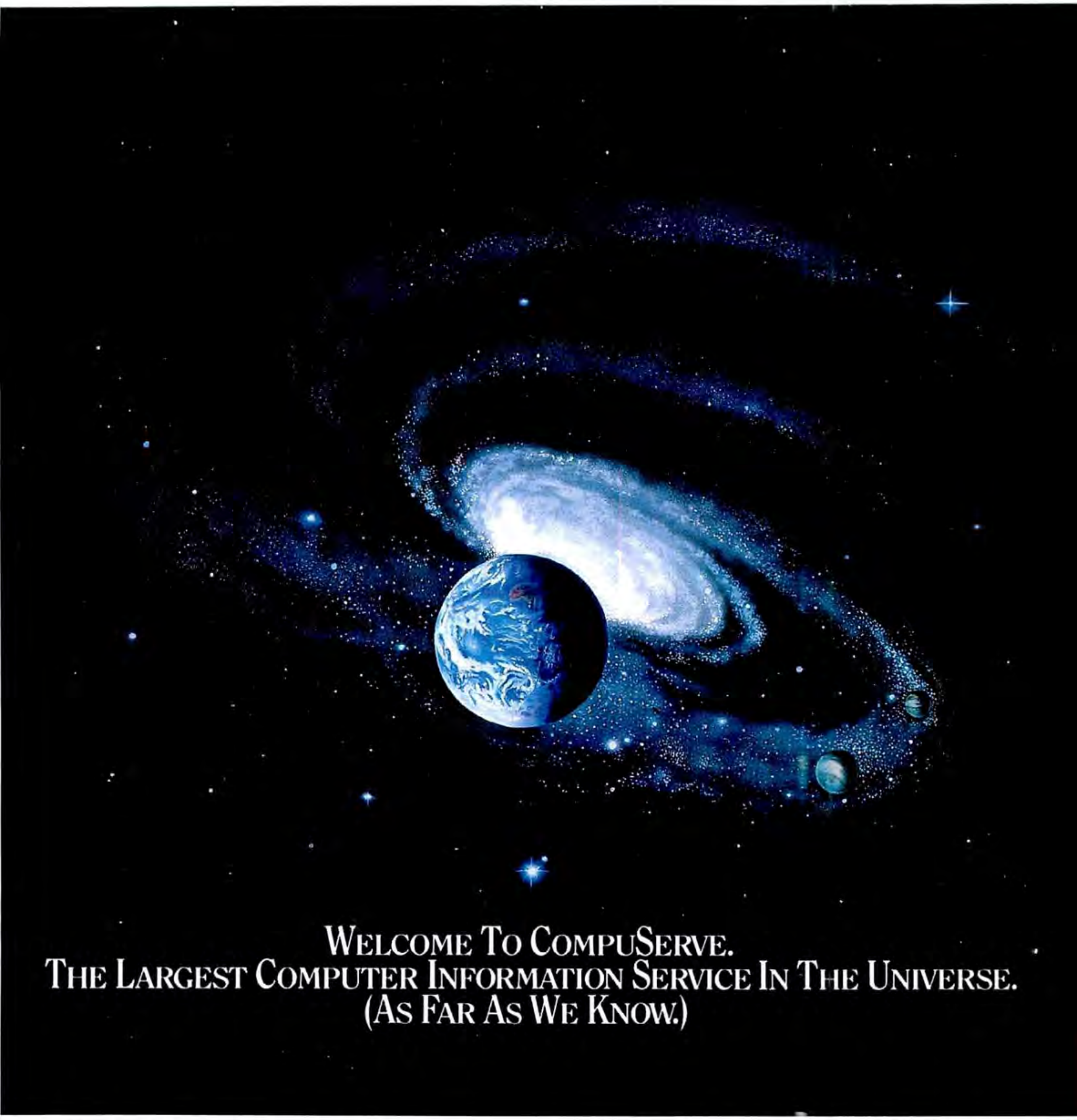
Ticket to Space

Ever since I was captivated by science fiction, I have been a "space buff." I've been to an aborted shuttle launch and have seen one land at Edwards Air Force Base. I've come to realize that the best way for us to get "out there" is through the private sector. NASA has done some fantastic things, but the cost and politics are a serious drag on what they can do. A small amount of research and development grants to the private sector as well as contracts for services would go a great deal further, I feel, in opening the "final frontier" than pouring lots of money into grand programs.

I hope your magazine continues to write about the efforts of the private sector to develop the various areas of commercial space activities. One of those areas, tourism, could be my ticket to space.

Bill MacIntosh
Fairfield, Ohio

FINAL FRONTIER welcomes your letters. Send them c/o Letters to the Editor, FINAL FRONTIER, P.O. Box 11519, Washington, D.C. 20008. Please type your correspondence and limit the length to 150 words.



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THE OBSERVATORY

The Next President on the Next Frontier

The candidates' positions on space policy.

▼ ▼ ▼

(Editor's note: Prior to this summer's presidential nominating conventions, FINAL FRONTIER asked the two apparent nominees, Vice President George Bush and Massachussetts Governor Mike Dukakis, for their views on the future of the nation's space program. Here are their responses:)

Governor Dukakis:

A generation ago, President Kennedy raised the sights and the spirit of all Americans by challenging our scientists and citizens to go forward with a bold program of space exploration. Sadly, in recent years our space program has lost its sense of purpose. Despite annual expenditures for NASA approaching $10 billion, our space program is in disarray, our space science program no longer leads the world and the aftermath of the Challenger accident has created doubts about the ability of the United States to operate effectively in space.

The time has come to renew our commitment to an imaginative, well-designed space policy, one that turns away from the fantasy of Star Wars and seeks again to explore space for the benefit of all mankind.

We should encourage commercial uses of space. I will foster private investment by creating partnerships between the federal government and the private sector that emphasize joint research programs. I will reinvigorate the White House Office of Science and Technology Policy to coordinate space efforts between government and private industry.

Rather than spend billions for projects which serve narrow interests—like the "Orient Express" spaceplane—we should emphasize research to benefit our nation and humankind as a whole. We must develop a comprehensive, long-term plan to assure stable funding for important space science projects.

I support returning the shuttle to flight with a reduced schedule to ensure higher safety standards, and building of a replacement shuttle orbiter. At the same time, there is a clear need to develop affordable alternatives to the shuttle, such as expendable launch vehicles.

We should review the options for a space station. There are a number of less costly alternatives to the station now envisioned by NASA; some of these could be in operation much sooner, and could perform most—perhaps all—of the requirements of a large, permanently manned station.

The continuing failures in our shuttle program are symptomatic of management gone awry. I will appoint skilled managers at NASA who will restore professionalism and competence to our space program, and who will set high standards for NASA personnel and contractors.

Finally, I will ask the Soviet Union and other spacefaring nations to join with us in more cooperative efforts. While we must protect sensitive technologies, they offer an unparalled opportunity to work together on projects which will benefit us all. We should also explore with other nations the feasibility of joint space engineering activities that might pave the way for a joint manned mission to Mars.

Vice President Bush:

I am committed to re-establishing America as the world's leader in space. Americans are explorers—we need to push back the frontier of our knowledge. Continued space exploration is vital to the nation's security and economic growth as well.

The new technologies resulting from space experiments have produced dynamic improvements in fields such as electronics and medicine. Just as important, space exploration provides our children, the next generation of scientists and engineers, with a sense of vision to encourage their imaginations and energies.

There are four specific aspects to my space program:

- The federal government should get out of the business of being a freight service for routine commercial payloads. I want to encourage the development of—not compete with—private commercial space development.
- I will create a National Space Council chaired by the Vice President and composed of the Secretaries of Commerce, Defense, State and Transportation, as well as the Administrator of NASA.
- I support construction of a replacement space shuttle and a heavy-lift launch capability that will provide us with flexible, reliable access to space. And I've strongly supported the development of a space station.
- I support "Mission to Planet Earth," which is a project designed to establish platforms in space to observe climactic changes on Earth. The information gained through this project will be of great value to farmers, fishermen, weathermen, scientists—all of us. □

GLOBAL CURRENTS

An Insider's Look at U.S.-Soviet Space Cooperation

Going hand-in-hand means going step-by-step.

▼ ▼ ▼

By Les Dorr, Jr.

At the end of a long interview just before the Moscow summit in May, Mikhail Gorbachev lamented the time and money being spent on arms in space by both sides. "In fact," said the Soviet leader, walking toward a model of a rocket booster, "I'm going to propose to Reagan that we should go to Mars together!" Instant cosmic brotherhood! The stuff of which front-page headlines are made.

Gorbachev's grandiloquent gesture lacked a few minor details, such as when we'd go, how we'd do it and who'd pay for it. But his was only the latest high-profile call for an international mission to Mars; scientists, entertainers and politicians all seem smitten with the idea of sailing off to the Red Planet with the Soviets early in the next century. A couple of years ago, we weren't even supposed to *like* these guys!

All the hoopla about Mars obscures the real progress in space cooperation being made by the United States and the Soviet Union. In April 1987, both countries signed an agreement listing sixteen projects that they considered good candidates for joint operations. During the last eighteen months, teams of Soviet and American experts have been meeting to hash out the details of implementing those programs.

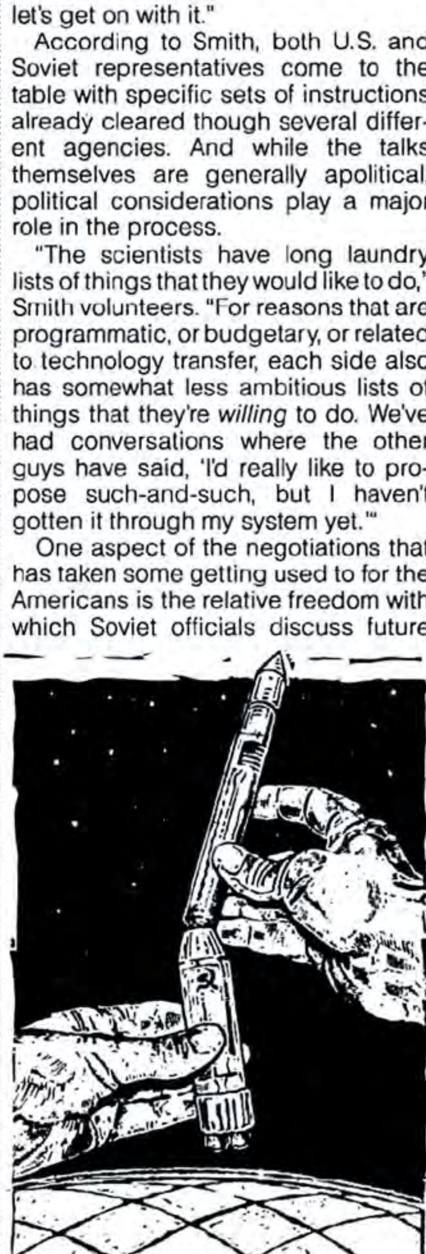
The pre-Glasnost stereotype of Soviet-American negotiations resembled a chess game: setpiece denunciations and defenses of national policies, followed by unacceptable demands and a recess to discuss strategy with higher authorities. A much different atmosphere, however, pervades the space cooperation talks.

"I've had those kinds of conversations with the foreign ministry types, people who get paid to do that kind of stuff," recalls Peter Smith, NASA's deputy director of international relations, who has been in on several rounds of negotiations with the Russians. "But the one adjective I would apply to our dealings with the Soviets on space is 'businesslike.' There's the realization that there's mutual benefit to be had, so let's get on with it."

According to Smith, both U.S. and Soviet representatives come to the table with specific sets of instructions already cleared though several different agencies. And while the talks themselves are generally apolitical, political considerations play a major role in the process.

"The scientists have long laundry lists of things that they would like to do," Smith volunteers. "For reasons that are programmatic, or budgetary, or related to technology transfer, each side also has somewhat less ambitious lists of things that they're *willing* to do. We've had conversations where the other guys have said, 'I'd really like to propose such-and-such, but I haven't gotten it through my system yet.'"

One aspect of the negotiations that has taken some getting used to for the Americans is the relative freedom with which Soviet officials discuss future space plans. Not so long ago, Soviet flights were blanketed in secrecy until they were on the launch pad. But last year, for example, the Soviets announced a bold ten-year plan for unmanned exploration of Mars, replete with detailed descriptions of sample-return missions, instrumented Martian balloon flights and surface rovers.


RICK ALLEN

"The assumption was that those projects were firm because the Soviets talked about them ahead of time," says Smith. "When they came back this year with a different spiel, we realized that they had learned 'NASA future program tense,' where you talk about missions and capabilities as if they existed and were operating, when in fact you haven't even gotten approval to do them."

In Smith's opinion, even discussion of joint *unmanned* flights to Mars with the Soviets would be "terribly premature," because neither NASA nor the Soviet space establishment has made the monetary commitment to such a venture. He notes that budget estimates for a Mars rover/sample return (one of the missions touted as a cooperative prospect) range from two to five billion dollars.

"The fact is that if we want cooperation on that scale, it's got to be funded. And right now it's not funded. So what we've agreed to do is to exchange the results of our studies of future missions to size up what's possible, and what the payoffs could be from cooperation."

Smith points out that whenever Soviet and American space experts get together, there's a lot of nonbinding conversation about the projects the two nations might be able to carry out. Ultimately, that may be the real benefit of the negotiations: the opportunity to exchange ideas and to get people used to working in harmony rather than in their own compartmentalized little worlds.

"If we continue to go step by step, building experience, building the *habit* of successful cooperation," says Smith, "you'll see measurable progress on a yearly, even a monthly, time scale." □

NOTES FROM EARTH

NO, NOBODY'S LISTENING

When President Reagan sent in his $11.5 billion request for the 1989 NASA budget, officials in the space agency's life sciences division were pleased, perhaps even a little amazed, that it included a healthy $101.7 million for their program. The President's figure would permit a start on several new projects, including a comprehensive search for extraterrestrial intelligence (SETI) to be turned on in 1992 ("Is Anybody Listening?" June 1988).

But in May, congressional budget committees started shredding the NASA request, and the life sciences budget was hit hard. The House appropriations committee cut it to just under $77 million, and the entire increase for SETI ($4.4 million) was axed.

"There's a reason for almost every other cut" except the life sciences cut, remarked NASA's associate administrator for space science and applications, Lennard Fisk, to the NASA life sciences advisory committee on May 31. "SETI's taken a beating, and I'm surprised."

In early June, the Senate appropriations committee further reduced NASA's appropriation for 1989. If the cuts are sustained, the agency will have to postpone its SETI project. Plans to develop life-seeking instruments for future unmanned missions to Mars and Saturn's moon Titan also may be cancelled.

No members of the congressional committees that authorize and appropriate NASA funds are known to oppose spending on SETI, but neither are any members strongly in favor of getting the program into gear. Staffers on the budget committees reported that SETI was not singled out; the increase requested for the program was sacrificed only because it was marked "new money."

NASA's SETI program manager, Lynn Griffiths, says researchers are at the point where they need money to build hardware in order to proceed. If the proposed budget cuts go into effect, that will be out of the question.

—Linda Billings

NASA

E.T.'s, don't phone. Nobody home.

RETURN TO MERCURY

The planet Mercury isn't a place you'd want to live, but it may be a good one to visit: researchers at the Jet Propulsion Laboratory (JPL) are studying the possibility of placing an unmanned spacecraft into orbit about the innermost planet.

"We just started doing this [study]," says JPL's Chen-Wan Yen, who notes that an orbiter could investigate Mercury far more thoroughly than did Mariner 10—the only other spacecraft to visit there—in 1974. Mariner 10 simply flew past the planet, whereas an orbiter could study it for many months.

But Yen's task is tough. When it arrives at Mercury, a spacecraft is traveling very fast. No problem for Mariner 10, since it was merely passing through. To *orbit* the planet, however, a probe must drastically slow its speed. And to do that, the vehicle must carry a lot of fuel for retro-rockets that would reduce its velocity. The result is an impossibly expensive mission in the current budgetary climate.

NASA

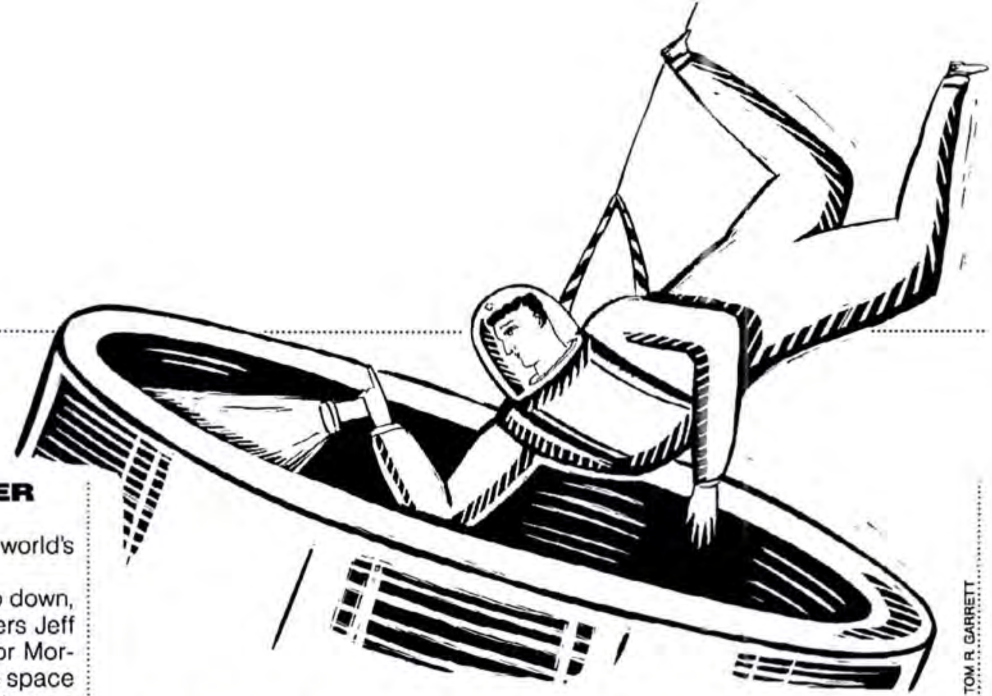
Mercury as viewed by Mariner 10. What's on the *other* side?

"The solution to that problem," says Yen, "is to swing by Venus twice, and then swing by Mercury two or three times." Each planetary encounter slows the probe; by the time it approaches Mercury the final time, the spacecraft is traveling slowly enough that it can easily orbit the planet. This innovative trajectory reduces the cost, but increases the flight time to between three and five years. In contrast, Mariner 10 made the trip in just five months.

Although Mariner 10 revealed Mercury's lunarlike landscape for the first time, it returned images of only half the planet. An orbiter could photograph the whole thing, and could also determine the planet's surface composition, which Mariner 10 didn't do. Yen also hopes the orbiter will study how Mercury's magnetic field interacts with solar radiation.

Should we even bother to go back to Mercury? "Of course," she says. "You're asking the wrong person if you want to get a negative answer!"

—Ken Croswell



TOM R. GARRETT

MY BORE-ING CAREER

What's it like inside the world's largest firecracker?

"Let's say the first time you go down, it has your full attention," answers Jeff Tuttle, a 31-year-old engineer for Morton Thiokol, manufacturer of the space shuttle's giant solid rocket boosters.

Suspended by a crane, Tuttle has made almost two dozen "bore entries"—trips down the dark, five-foot diameter centers of the shuttle boosters—to inspect design changes made since the Challenger explosion. His job included checking out Discovery's solid rockets prior to the STS-26 mission.

Each booster is filled with 1.1 million pounds of live propellant, and Tuttle's biggest fear is creating a static charge that would set it off. To avoid that, he wears 100 percent cotton garments under anti-static, flame-retardant coveralls. Special wrist bands drain off his body's natural charge through ground cables. Once he's outfitted, spotters give him the once-over with an electrostatic discharge meter. They hand him a super-bright, explosion-proof spotlight, and he's ready to go.

"I visually verify that each field joint has a good seal," says Tuttle, an expert on the boosters' improved insulation. Specifically, Tuttle confirms that the J-seal—an insulation component—fits snugly.

"The J-seal is the newest, most important part of the sealing function of the joint," explains Tuttle. The new seal helps retain the hot gas created when the segmented boosters ignite, preventing leaks like the one blamed for the Challenger disaster.

Because even the smallest spark inside a booster could set off a catastrophic pyrotechnic display, Tuttle is quite happy to take "extreme safety precautions. Simply put, I love me," he says.

—*Beth Dickey*

SHUTTLE SCHEDULE REDUX

Just when you thought it was safe to tack your Space Shuttle Launch Schedule (DataBase, April 1988) up on the wall, NASA has shuffled some of the vehicle's upcoming cargoes and flip-flopped two of its missions.

Columbia's **STS-28** flight will now take place about six weeks *after* the **STS-29** mission of Discovery. The switch was made to minimize the impact of ground-based processing work on the time-critical **STS-30** launch. That flight has a narrow April 1989 "window" in which to fire the Magellan spacecraft toward Venus.

Wholesale changes also have been made to the payloads and orbiters assigned to several flights:

STS-32: Columbia will now carry the Syncom IV-5 communications satellite into space on this mission, and retrieve the Long Duration Exposure Facility (LDEF) before it falls from orbit ("Notes From Earth" August 1988.)

STS-35: The Astro-1 ultraviolet telescopes have been bumped to this flight, and a new Broad-Band X-Ray Telescope has been added.

STS-37: Discovery is now scheduled for this mission. Onboard will be three Department of Defense experiments.

STS-38: Columbia will haul the Spacelab module into orbit for a life sciences mission (SLS-1). The previously planned Starlab astronomy mission shifts to a later flight.

STS-39: The Gamma Ray Observatory moves up a notch to Atlantis' flight.

STS-40: Now a classified Defense Department mission onboard Discovery.

STS-41: Assigned to Columbia, with Starlab in the cargo bay.

STS-43: The first Atmospheric Laboratory for Applications and Science (ATLAS-1) replaces original payloads.

NASA also has announced the astronauts who will fly Missions 28 through 31.

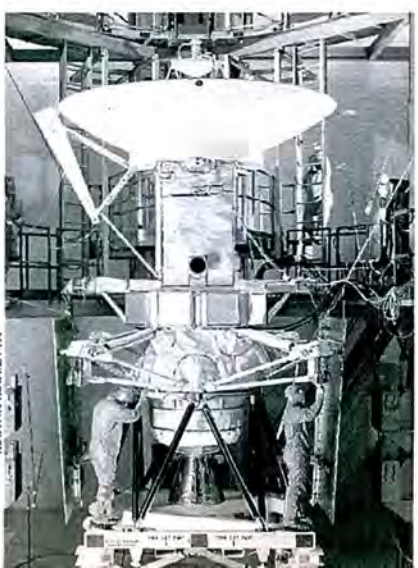
Brewster Shaw will command **STS-28**, with Dick Richards as his pilot. Mission specialists will be David Leestma, James Adamson and Mark Brown.

Mission 29 lists Mike Coats as commander, John Blaha as pilot, and James Buchli, Robert Springer and James Bagian as mission specialists.

Dave Walker and Ronald Grabe will fly Atlantis on **STS-30**. Norm Thagard, Mary Cleave and Mark Lee round out the crew.

Mission 31 will be commanded by Loren Shriver. Charles Bolden is assigned as pilot, with mission specialists Steve Hawley, Bruce McCandless and Kathy Sullivan slated to deploy NASA's long-awaited Hubble Space Telescope.

—*Les Dorr, Jr.*



MARTIN MARIETTA

The Magellan Venus probe: Number five on the runway.

Notes From Earth

SUPERCONDUCTORS: WATCH THIS SPACE

Superconductors have grabbed the attention of the scientific community, and NASA is no exception. Space agency researchers believe that superconducting materials, which transmit electric current without losing energy to internal resistance, could unlock an unseen portion of the electromagnetic spectrum, and may yield more accurate timing clocks for satellites.

NASA is looking at detectors that will be able to examine the sub-millimeter portion of the electromagnetic spectrum, an area to which current sensors are blind. With such equipment, astrophysicists may be able to "capture" these emissions from galaxies, stars and other astrophysical phenomena to learn more about the evolution of the universe.

According to Martin Sokoloski, NASA's manager of Communications and Sensor Technology, superconductors might also be used to improve the accuracy of the precise clocks that position satellites and switch on instruments for scientific observations.

There's no real time frame for turning these ideas into reality, said Sokoloski, despite their promising space applications: "More superconductive materials are being discovered, so picking one material now and trying to extend it into space isn't practical."

Two superconducting technologies, thin film and ceramics, are being studied. The first space applications are likely to use the thin film technique, since current ceramic material is "anti-anisotropic"—current flowing in one direction can be superconductive, but current perpendicular to the first flow is not.

"It's going to take time to get a material with the best electrical properties," Sokoloski said, "but the class of materials that can become superconductive hasn't been exhausted. We have the time."

—*Jim Harroun*

COLD WARS IN ORBIT

The Soviet Union is collaborating with an Australian researcher to send a viral protein crystal experiment into space, which some Pentagon officials fear could help the Soviets wage biological warfare against the United States or its allies. What they find most disturbing is that the research has been funded for the last decade by American taxpayers.

But other government officials, after examining the issues involved, have decided that the test involves only basic research and that Defense Department concerns are overblown. Graham Laver, the Australian researcher involved in the project, agrees.

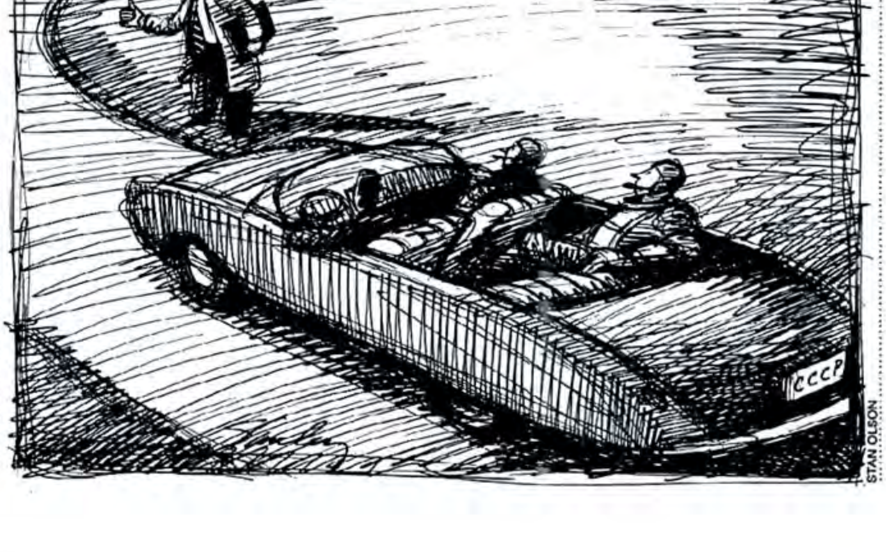
All Laver wants to do is cure the flu. The experiment involves putting a protein crystal growth apparatus aboard the Soviets' Mir space station. Inside the device will be neuraminidase, the enzyme that allows the flu to attack human cells. Because Laver will investigate how cells defend themselves against the enzyme, his work also has implications for AIDS research.

In the low gravity of space, Laver hopes to grow crystals larger than those grown on Earth—specimens that may reveal new information about the structure of the flu enzyme. As one of the first Westerners to join with the Soviets in a Mir project, Laver also may be opening new avenues for U.S. researchers. There are already several projects in the pipeline that American scientists want to fly aboard Mir.

One venture, proposed by Peter Tsou of NASA's Jet Propulsion Laboratory, involves a kind of cosmic dust collector designed to test the origins of life in the universe. The collector, made of aerogel (a less dense version of the clear material commercially available as window insulation), could trap interplanetary dust particles intact, with minimal alteration of their basic structure.

Such "fossils" of an earlier universe are contaminated by the Earth's atmosphere, and must be gathered in open space. NASA officials hope that the recent agreement to collaborate with the Soviets on space projects will expand to allow such basic scientific cooperation, not only to find out how life began on Earth, but to help keep it from catching cold.

—*Melinda Gipson*



WHEN GOOD SATELLITES GO BAD

The National Oceanic and Atmospheric Administration (NOAA) is now marketing two computer software tools that may help satellite designers predict when and where their orbiting machines might fall prey to space invaders.

The agency got into the bug business in 1982, when satellite operators began calling for clues as to why one glitch or another had occurred. "We began collating the list of dates, times and locations of any malfunction," Allen says. "Several operators went through their files. We pulled whatever we could, the conditions on the Sun, whatever we knew."

CREME (Cosmic Ray Effects on Microelectronics) is a mathematical model from the Naval Research Laboratory that generates a "best guess" of a satellite's behavior in a particular orbit. SAM (Space Anomaly Base) is a customizable "laundry list" program, written by NOAA, that catalogues almost 2000 electrical malfunctions reported on orbiting satellites. Users can then take these reports and compare them against data on magnetic storms, weather conditions, launch locations, orbits, auroral displays and other factors that might have caused a satellite to develop a glitch.

NOAA scientist Joe Allen says that the agency's official instructions are for users to "mix and draw their own conclusions" from these data. A strong hypothesis, however, is that solar flareups and resulting magnetic storms are the cause of many of the electrical breakdowns in space.

Many failures show up in the spring and fall, Allen says, which ties in with seasonal increases in magnetic storms. Is there a connection?

NOAA won't say "yes," although Allen will be the first to tell you there's a strong case for blaming many orbital woes on storms in space. Right now, NOAA just wants the program to have as many users as possible, and in return, to collect more data.

—Maura J. Mackowski

U.S. NAVAL OBSERVATORY

Asaph Hall in his Naval Observatory days, and the telescope with which he discovered the moons of Mars.

HAULING ASAPH TO PHOBOS

Imagine that a memo you sent to your boss reporting some wonderful discovery eventually ended up on the wall of your company's national headquarters as a cherished tribute to your efforts. Magnify that feeling by about 40 million miles—plus a lifetime's dedication—and you'll know how Asaph Hall would have felt had he known that 111 years after his discovery of the Martian moons Phobos and Deimos, a page from his notebook recording the sighting of the moons would be mounted on a Soviet spacecraft set to land on Phobos next spring.

Although the idea for a commemorative plaque was formally presented to the Soviets by NASA, the project began as the dream of Hall's great, great grandson, Andrew Hyde of Alexandria, Virginia. Hyde, a staff member for Senator John Warner, proposed the idea to NASA officials soon after he learned of the Soviets' plans to attempt a flight to Phobos.

The plaque was designed at the Naval Observatory in Washington, D.C., where Hall was employed at the time he made his discovery in 1877. Anodized in gold, the aluminum plaque will be mounted on the side of one of the two Phobos landers. At this point no one is sure which craft will "wear" it, nor are they sure which size plaque is going to be used. The designers at the Observatory, uncertain how much space would be available, sent the Soviets several different plaques ranging from postage-stamp size to 6" square.

"My great-great grandfather has always been a source of inspiration to me and my family," beamed Andrew Hyde. "Never in his wildest imagination could he ever have imagined this. He would be very proud."

—Bryan Reichhardt

Galactic Events

September-December, Washington D.C. The Smithsonian's National Air and Space Museum has a new exhibit called "The European Space Agency," which will run through the end of the year. The exhibit highlights seven space science missions sponsored by the European consortium, and will feature displays of spacecraft such as Ulysses, which will explore the polar regions of the Sun, and the Giotto probe that visited Halley's Comet in 1986. For information, call (202) 357-1300.

September. The National Space Society's Dial-a-Shuttle service resumes with the launch of Discovery. For a charge of $2.00 for the first minute and 45 cents for each additional minute, callers can hear live conversations between astronauts and Mission Control, along with taped interviews and more. Call 1-900-909-NASA anytime during the STS-26 mission.

THE PRIVATE VECTOR

Will a Space Superfund Fly?

A taxing proposition for the aerospace industry.

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By Melinda Gipson

Space exploration doesn't come cheap. New, ambitious projects like a lunar outpost or a human expedition to Mars could require that NASA's current budget be tripled by the turn of the century, to something on the order of $30 billion a year, according to a recent study by the impartial Congressional Budget Office.

Just to keep even with planned space station developments, NASA will need a billion dollars next year—money that has to be weighed against other worthy federal expenditures such as veterans' medical care and low income housing. Congressional committees already have trimmed the space agency's budget, and the best NASA may be able to hope for in this era of deficit reduction is enough money to stretch the multi-billion dollar station into the next century.

One of NASA's more vocal supporters, New Jersey Democrat Rep. Robert Roe, believes the space program should get more credit for the wealth it *returns* to the economy. For a decade, he has argued that every dollar spent in space creates seven dollars of economic value in the form of spinoffs—high technology products and processes. Now Roe, head of the House Science, Space and Technology Committee, is proposing some radical ideas on how to prove it.

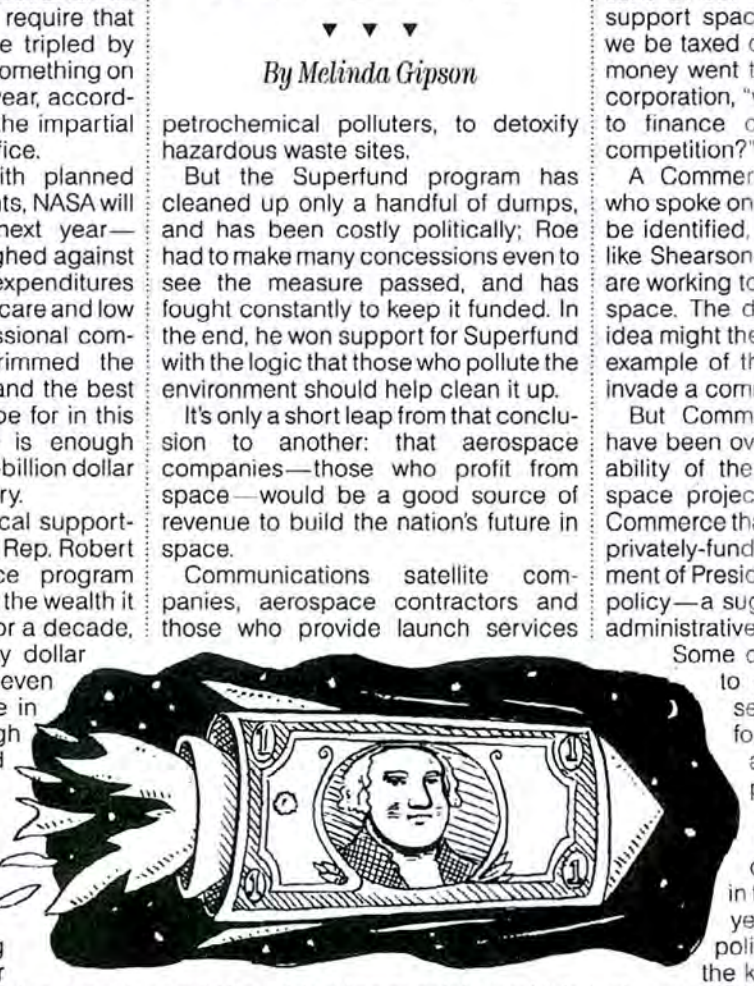
"How about establishing a national trust fund for space?" suggested Roe at a recent industry gathering. "We've built and maintained a highway structure through the highway trust fund. There's no reason why we can't build infrastructure in space the way we do on the ground."

Roe said he doesn't yet know exactly how the trust fund will work, but sources close to the congressman say it might resemble Superfund, the massive environmental cleanup program that Roe pushed through Congress in 1980. Superfund is a $1.6 billion pool of cash, established by taxes levied on petrochemical polluters, to detoxify hazardous waste sites.

But the Superfund program has cleaned up only a handful of dumps, and has been costly politically; Roe had to make many concessions even to see the measure passed, and has fought constantly to keep it funded. In the end, he won support for Superfund with the logic that those who pollute the environment should help clean it up.

It's only a short leap from that conclusion to another: that aerospace companies—those who profit from space—would be a good source of revenue to build the nation's future in space.

Communications satellite companies, aerospace contractors and those who provide launch services could be subject to a special tax, which would be funneled into a space trust fund. Roe plans Congressional hearings this fall on how such tax monies could best be used to fuel the space program.


TOM R. GARRETT

Another idea is that government might join with financial institutions to create a national space development corporation. The money would serve as a pot for space venture entrepreneurs to borrow against to finance their ideas.

Roe's colleagues whose constituents include aerospace corporations can brace themselves for complaints: "We're spending (fill in the blank) millions of our own research money to support space projects. Why should we be taxed on top of that?" Or, if the money went to a space development corporation, "why should we be forced to finance our next generation of competition?"

A Commerce Department official, who spoke on the condition that he not be identified, said private companies like Shearson-Lehman-Hutton already are working to raise venture capital for space. The development corporation idea might therefore be "just one more example of the government trying to invade a commercial space market."

But Commerce officials generally have been overly optimistic about the ability of the private sector to fund space projects on their own. It was Commerce that put forth the notion of a privately-funded Moon base as an element of President Reagan's new space policy—a suggestion that died in the administrative advisory committee.

Some observers say Roe is on to something in trying to seek alternative financing for space ventures. After all, COMSAT, a public-private partnership, was successful in getting the satellite communications industry started in the 1960's. But it may take years of debate and many political concessions to craft the kind of program that can win support from the space industry.

In the meantime, Roe thinks the best way to demonstrate public support for space may be through an even more direct appeal to America's pocketbook: space bonds.

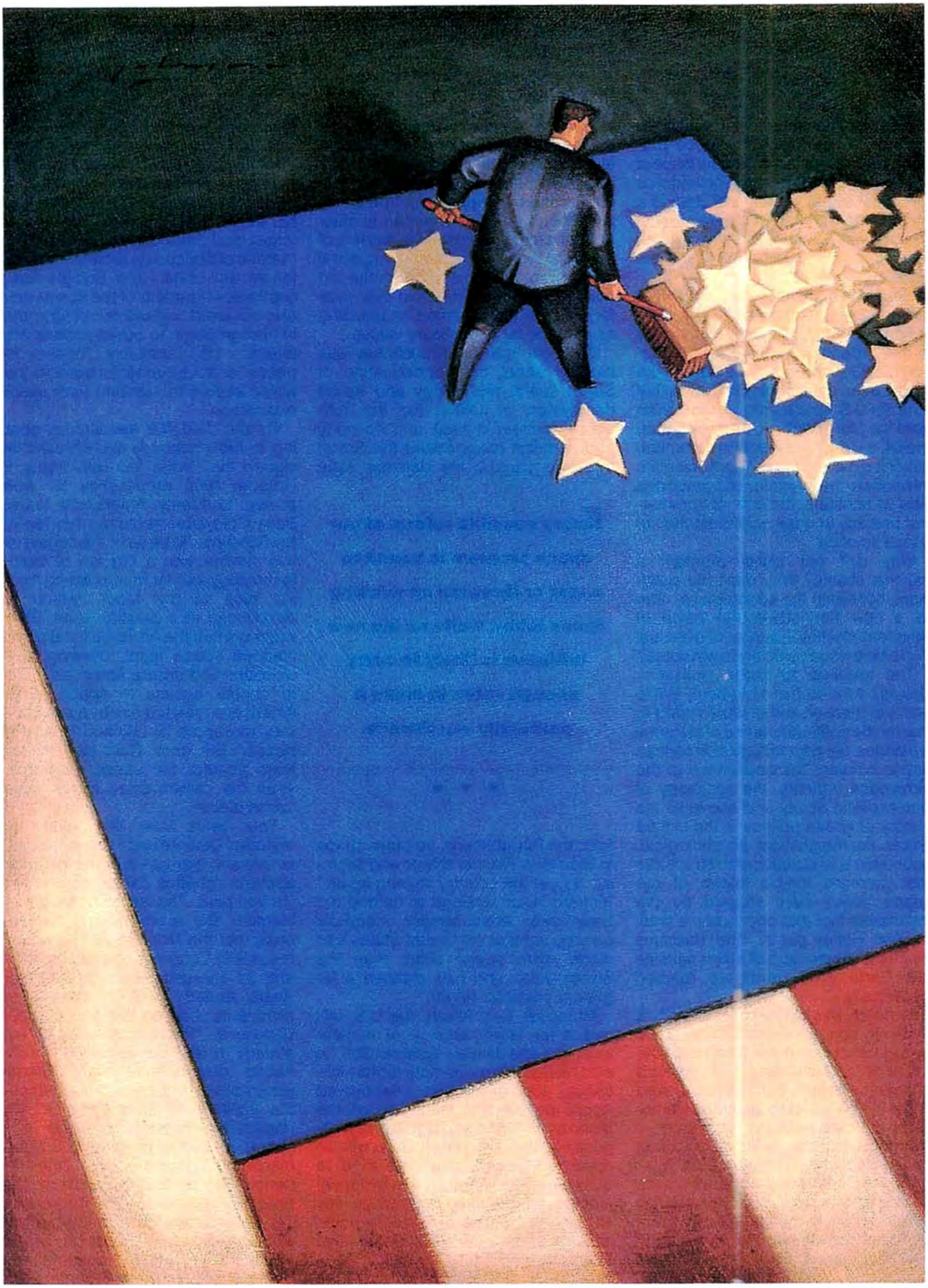
"Why not?" says the New Jersey congressman. "The people of America should be offered the opportunity to fund something they believe in, something that can affect the future of their grandchildren. We're all looking to generate an idea that's workable, and these are just some of the things we're considering." □

Space, Politics and the Next President

Why You Won't Get To Vote For Mars In '88

The [Sputnik] issue is one which, if properly handled, would blast the Republicans out of the water, unify the Democratic party and elect you President." So wrote George Reedy to Senator Lyndon Johnson in autumn 1958 with the answer to the Democrats' problem in the 1958 and 1960 elections. The civil rights movement was alienating the Dixiecrats and tearing the party apart. The only hope was "to find another issue which is even more potent," and that was Sputnik. For "the important thing," Reedy sensed, "is that the Russians have left the Earth and the race for control of the universe has started....If the issue has merit, the politics will take care of themselves."

BY WALTER A. McDOUGALL



STEVE JOHNSON

Just imagine a moment in which the lethargy of the American space program was not only an important issue of national debate, but one so powerful as to cancel out all others and decide a presidential election! But the historical moment was fleeting, it could never recur in the same way, and so far it has not recurred at all.

Americans are about to hold their seventh presidential campaign since John F. Kennedy squeaked out victory in that "space and missile gap" election of 1960, and not once has space policy been a major factor. During that time the U.S. space program has fallen from the glory of Apollo and the Saturn rocket, a virtual monopoly in communications satellites and brilliant scientific missions to the ignominy of a grounded fleet of boosters, the loss of commercial primacy and the near extinction of space science.

Why isn't our ailing program a national shame? Why don't our politicians condemn the space mess, offer us a new Kennedy-esque vision of America's destiny in space, or even just exploit the issue cynically to win votes?

The answers to those questions should be the stuff of a big book. But to uncover them an author would need to master the political science of electoral dynamics, the psychology of American public opinion, the economics of the aerospace industry, the sociology of bureaucratic decay and above all the history of space politics in the United States. For the political, psychological, economic and bureaucratic structures that currently inhibit reform of our space policy were shaped by the intractable fact that once upon a time, as Eric Hoffer put it, "the Russians placed a medicine-ball sized satellite into Earth orbit (and) we reacted hysterically."

Kennedy was far from committed to a dynamic space program in 1960. He was ignorant of and skeptical about the future of "rocket ships." It all smacked of science fiction. But Sputnik proved to be the galvanizing issue the Democrats needed because, at bottom, it was not about science fiction but about national security. The years from Sputnik to the Cuban Missile Crisis were the height of the Cold War. Khrushchev used his space spectaculars as proof of Soviet missile superiority, which in turn buttressed his "rocket-rattling" diplomacy. Few Americans understood what "space" was all about, but they did know that giant Russian rockets and artificial moons were scary. What was more, Soviet missile prowess undermined European confidence in the efficacy of the American nuclear umbrella and impressed the leaders of the Third World states emerging, at the same historical moment, from the old colonial empires. The Cold War race for prestige thus seemed as pressing as the race for real military values.

We know now that Khrushchev was bluffing about the sophistication of Soviet space technology and Soviet deployment of ICBMs. But the truth wasn't so clear in 1960, and Kennedy and Johnson exaggerated the Soviet threat to capture the defense issue from the Republicans, tie outer space to their New Frontier theme and promise "to get the country moving again." Richard Nixon, obliged to defend the Eisenhower Administration, correctly pointed out that the United States had made more space shots than the Soviet Union and had gleaned a far greater scientific return.

Every possible reform of our space program is bound to anger or threaten an existing space lobby, while no big new initiative is likely to carry enough votes to make it politically worthwhile.

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Moreover, said Nixon, the U.S. still had a far larger arsenal of nuclear weapons and delivery systems. Still, he also pledged to move more rapidly into space, touting NASA's unapproved Apollo proposal to land men on the Moon by 1970 and adding: "It is entirely possible that this target date will be advanced." Each candidate tried to outpromise the other at this historical juncture when space technology was all fear and promise. Switch a few votes in Texas and Illinois and it might have been Nixon, not Kennedy, who exhorted Americans to land men on the Moon by the end of the decade.

In 1964, hyper-enthusiasm was still in evidence. Johnson picked up the fallen Kennedy's banner, pledged himself to a vigorous civilian space program (that he, as Senator, had done so much to forge), and drafted the symbolism and rhetoric of Space Age technocracy into the service of his Great Society. But a subtle downgrading of the space race also occurred. Instead of linking space in his campaign to Soviet rockets and threats, LBJ stressed "space for peace" and the economic benefits that would accrue to mankind from space exploration.

For the Cold War was already abating. In 1963, Kennedy and Khrushchev signed the Partial Test Ban Treaty. In October 1964 Khrushchev fell from power. Suddenly Americans feared Barry Goldwater more than they feared the Russians. To be sure, the conservative senator was a big fan of space technology, but far from pushing Apollo's race to the Moon, which he denounced as a prestige stunt, Goldwater wanted the Air Force to take over manned space flight, develop laser weapons and ensure America's ability to control access to space. When Americans rejected him by a landslide, they, too, opted for LBJ and "space for peace." But once Cold War military fears abated, the space program—even the civilian one—lost a major *raison d'être!*

Four years later this trend had matured. Detente was in the air abroad, smoke and tear-gas at home, billowing above the ghettos, campuses and convention halls. The issues of 1968 were Vietnam, the economy and law and order, not the Moon race. The honeymoon with Congress enjoyed by NASA and its energetic maestro James E. Webb ended in 1967 when three astronauts died on the pad at Cape Canaveral. The NASA budget was already in decline, with much of the Apollo development work already accomplished. Liberals condemned the "military-industrial complex" and demanded transfer of funds from space to social programs. Environmentalists, hippies and feminists denounced big technology as macho, polluting, alienating and oppressive. The Outer Space Treaty of 1967 and the seeming Soviet concession of the Moon race further weakened the defense and prestige arguments for

the space program, while economic arguments for the space program began to ring hollow.

If our goal was to improve life on Earth, said the critics, then why not spend money on people "here on Earth" rather than hoping for unspecified spin-offs from space? Candidates Nixon and Hubert Humphrey pledged to see Apollo through, but dared not issue new space challenges to an exhausted nation. The candidates also harbored deep resentment toward Kennedy, whose image was indelibly stamped on the space program.

"Come home America" was George McGovern's slogan in 1972. And although the public rejected his radical, isolationist platform, the mood he expressed was already evident in the first Nixon Administration. "Come home America" was the message of Vietnamization, the Nixon Doctrine, the decoupling of the dollar from gold and detente with the Soviet Union and China. Apollo was the last relic of Kennedy's "pay any price, bear any burden" mentality, and even though it triumphed brilliantly from 1969 to 1972, Nixon cancelled the last two Apollo flights, most of the Apollo Applications Program and the Air Force's Manned Orbiting Laboratory. When Vice President Spiro Agnew touted a manned Mars program, reporters laughed, the nation groaned and Nixon was silent. NASA morale collapsed along with its budgets, scores of its best engineers left for the private sector and thousands of new PhDs, trained to meet the "emergency" exploited by Kennedy, were out of work.

NASA, fearful of collapsing back into a small research and service agency like the old NACA, begged the Nixon Administration to approve a new big project. It finally succeeded, thanks to the only remaining electoral value of the space program: as a source of jobs for an aerospace industry depressed by the space bust, cessation of missile and bomber deployment, banning of ABM systems in SALT-1 and cancellation of the SST. Aerospace unemployment meant trouble for Nixon in 1972 in California, Texas and Florida unless he gave his blessing to a substantial "metal-bending" project. And so the space shuttle was born, not of sober long-range planning, but of short-term political expediency—and only then on the condition that it be built on a shoestring and somehow "pay for itself."

In retrospect it was a terrible mistake, but what alternative did supporters of NASA have but to make the best of whatever the Republicans gave them? After all, McGovern had no use for a space program described by liberal pundits as "welfare for the military-industrial complex," and by 1976 the Democrats had completed their metamorphosis from the party of technocratic optimism and confident anticommunism to the party of no-growth redistribution, environmentalism, pacifism and pessimism. Democrats of the Kennedy, Johnson, Stuart Symington or Scoop Jackson type—the original promoters of the space program—were gone. Jerry Brown's "new age" enthusiasm for the potential of space earned him ridicule as "Governor Moonbeam," Jimmy Carter made a bid to go down in history as the engineer who revolted against engineering, and his running mate, Senator Walter Mondale, was a leading critic of the space program.

We must then encourage the young minds of America to get to work on real solutions to the space launch problem. Where are those minds to be found?

What was more, the shuttle program, though underfunded, still absorbed such a large chunk of NASA's budget that programs in space science and applications withered away. Bereft of its best talent and succumbing to bureaucratic sclerosis, NASA failed the test of courage. Even when it became clear, by 1978 or 1979, that the "revolutionary" shuttle, meant to open a "new era" in space, could never meet its schedule, performance and cost specifications, the agency did not protest, few officials resigned, and no one blew the whistle.

Into this void, in 1980, stepped Ronald Reagan. He was the first president since Kennedy with a real opportunity to redirect and revivify the space program. He had much in common with Kennedy, calling as he did for lower taxes, stronger defense and a revival of the can-do Yankee spirit after the "malaise" of Watergate and the Carter years. NASA's new chiefs, James Beggs and Hans Mark, rushed the tardy and troubled shuttle to operational status after only four flights and lobbied the President to make a Kennedy-style gesture for space. In 1984, the next election year, they did persuade Reagan to call for deployment of a manned space station "within a decade."

But the station suffered at once from confusion over its purpose, delays and overruns in the shuttle program and worries over the budget deficits. Moreover, Reagan had already invested his political and financial capital, in March 1983, in the Strategic Defense Initiative ("Star Wars"). Still, one would have expected Reagan to make a big pitch for space in the 1984 campaign. If he were serious about SDI, the country would need a large, economical fleet of launch vehicles as well as a hardy NASA program to show the world that the United States was not bent on "militarizing space." Instead, Reagan said almost nothing about space in the 1984 campaign—and why

should he, when his opponent, space nemesis Mondale, could be expected not to compete for the issue?

Then the Shuttle blew up...and the Delta and the Titan. The deficits grew even larger and Gramm-Rudman became law. Then detente made a comeback with the INF treaty and plans for 50 percent reductions in the nuclear arsenals. All the conditions that might have sustained a big, new push in space evaporated. Even the talk of "America in decline," based on Paul Kennedy's *The Rise and Fall of the Great Powers*, brings calls for retrenchment rather than resurgence. So now we stumble into the 1988 election with the space program moribund and not a single candidate presenting a vision and a plan for America in space. Let's go to Mars with the Russians, said Al Gore. Such is the level to which the debate has sunk.

Dreamers still abound, however, and they have a plethora of plans. Reagan's National Commission on Space, the Sally Ride Commission, the Rogers Commission and all the space clubs and magazines have suggested solutions to our space mess and goals for the next 25 years. Investigative journalists have dug up the incompetence, timidity and poor judgment leading to the failure of the shuttle program. But dreaming dreams and even facing up to past mistakes are not the same as nudging politicians to embrace reforms. For every possible reform of our space program is bound to anger or threaten an existing space lobby, while no big new initiative is likely to carry enough votes to make it politically worthwhile.

Let us review those mistakes and possible reforms. First, there was the "Kennedy effect" itself, which made the space program appear to the nation as a one-time race, and established the pattern of "big single goals" that inhibited steady, sensible space development supported by steady, sensible budgets. Apollo also locked NASA into manned spaceflight programs on the assumption that people-in-space was what persuaded the public to support the budget. To give NASA its due, the agency was almost forced into arguing for a big manned program as the "logical next step" after Apollo, or else it would have had to admit that Apollo had not been a "logical first step"!

But the argument that manned spaceflight functions as a loss-leader bringing in monies for other, less sensational projects is valid only when the goose is fat. In lean times the shuttle—and arguably the station- will eat up almost all of NASA's budget to the detriment of science and applications. Finally, much of the aerospace bureaucracy and industry shaped by Apollo and the shuttle would stand to lose from a radical shift away from manned spaceflight and super high-energy boosters.

Nixon's decision, ratified by Ford and Carter, to build the shuttle on the cheap also had dire effects. The shuttle wasn't cheap: we merely traded low development costs for far higher operational costs and failed to reduce the cost-per-pound to orbit at all. Instead, to make the shuttle seem economical, NASA demanded and got the phasing out of most expendable launch vehicles, leaving the space program—and thousands of bureaucrats and engineers—dependent on a flawed system.

Reagan's people made another fatal error in 1981 when they failed to push private enterprise in space according to their own free market philosophy.

Americans are about to hold their seventh presidential campaign since John F. Kennedy squeaked out victory in the "space and missile gap" election of 1960, and not once has space policy been a major factor.

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Instead, they bought the NASA line and squelched private space initiatives in favor of the shuttle. The Reagan Administration also did little to solve the boondoggles over communications satellite research, LANDSAT operations and space science, dooming the United States to international impotence in an industry once touted as the symbol of American greatness.

What solutions are put forward by the "experts"? The National Commission on Space pushes the space station, Moon colonies and a Mars voyage at a time when even our basic boosters aren't flying. Isn't this Fantasyland rather than Tomorrowland? The Ride Report tells us that leadership is a "process" (whatever that means) and repeats the old clichés about national prowess and pride. The Reason Foundation makes a strong case for privatization of space, but ignores the structural interest groups and entry costs that would make sweeping privatization politically and financially painful. Isaac Asimov, in FINAL FRONTIER's premiere issue, says "Let's build space station...let's build observatories, laboratories and factories in the space between here and the Moon.... Let's even build space settlements...."

But the last thing we need is more "Let's do this or that" boosterism. Barring some Soviet breakthrough as shocking as Sputnik (which presumably none of us wants) the public will just answer "Why?" and "How much will it cost?" and "How long will it take?" and "How much money will be wasted by inefficiency and corruption?," and then will double or triple those numbers out of cynicism. To be sure, public support for the space program has held to a surprising degree, even after Challenger, but the public also is skeptical. A strong space plank would be too big a risk for any presidential candidate to take in the current climate of budgetary austerity and space flops.

How about Congress? Could it lead a political offensive on behalf of the space program? Back in the late 1950s—when each house of Congress set up standing committees for space, the missile gap was a national issue, and federal spending expanded rapidly—Congress could push for NASA. But the committees were downgraded during the first Nixon term, Congress came to view space spending as "discretionary," and space-conscious legislators became relatively isolated.

What's more, any sharp change in space policy—from the Shuttle to expendable rockets, from NASA to the private sector, from the big aerospace firms to space "entrepreneurs," from "gold-plated" high-tech systems to cheap, reliable boosters or a new launch technology—would only damage a Congressman's friends in NASA and industry.

Indeed, NASA and the aerospace firms themselves would be reluctant to support far-reaching reform of the space program. First, any political campaign stressing our "space mess" would remind the public of the blunders of the past perpetrated by politicians, NASA, Morton Thiokol, Rockwell and others. Second, a revolutionary approach to spaceflight might break, or at least loosen the grip that NASA and its big contractors have on the public purse. For NASA, Congress and the aerospace industry comprise what the Reason Foundation calls an "Iron Triangle" of interlocking interests with a heavy stake in "business as usual." We are living with precisely what Eisenhower predicted: a military/industrial and scientific/technological complex with "inordinate influence"

continued on page 58

THE WORLD'S

HIGHEST ROLLERCOASTER

We road test NASA's zero-gravity Learjet. ■ BY RAY SPANGENBURG AND DIANE MOSER

A couple of feet to the left of your head, you're suddenly aware of a small, white object strangely suspended in midair. You reach out your hand instinctively and effortlessly to scoop it up. It's a piece of styrofoam that must have worked loose from some unknown crevice in the aircraft. You let go, but it stays in place floating in front of your eyes, magically, like a laser image. Suspended two inches above your seat, held safely only by your seat belt, your body begins to bend forward, your arms floating free. Your head brushes the cabin roof as you reach out again for the insignificant little "peanut," currently the most solid thing in your world, and tuck it into your shirt pocket for safekeeping.

And then, just as suddenly as you entered this strange new world, you're out of it again—like stepping through Alice's mirror for 30 seconds and then being yanked backward into the world of reality.

It's one of those idyllic California spring days full of sun, surf and zephyr-chased clouds as we soar high over the blue-green Pacific, on the world's longest rollercoaster ride. Technically, it's a flight maneuver NASA calls a "Keplerian Trajectory," or, more disturbingly, "a free-fall path." Our vehicle: a Learjet 24, part of the fleet of research aircraft at NASA's Ames Research Center, flying out of Moffett Field. What we have just experienced is NASA's answer to Newton, described casually in a technical paper as a method whereby "zero gravity environments can be produced inside aircraft."

THE STOCK MARKET: J.F TOWERS

"So you guys are going to go through with it," our pilot, Jim Martin, said with a somewhat wicked grin when he first saw us earlier that morning. We smiled back a bit thinly and both reluctantly refused a cup of early-morning coffee. The less in our stomachs, we reasoned, the better.

Self-confident, with just the slightest hint of cockiness, Jim Martin looks like he probably read "Steve Canyon"

NASA

The Learjet 24 awaits its next victims on the runway at Moffett Field.

comic strips avidly as a kid, decided he was going to be exactly like that, and then managed to pull it off. As an Air Force pilot, Martin flew the KC-135 "vomit comet" (a modified version of the Boeing 707) back in the days when they used it to train the Apollo astronauts for weightlessness. Now, as Chief of Flight Operations at Ames, he flies everything from experimental Harrier jets to the C-141 Kuiper Airborne Observatory used for astronomical studies, to the Learjet we're boarding today.

Our flight plan: Head out of the valley and about 100 miles down the coast to a patch over the water where the air traffic is light. There we'll be flying a maneuver much like the "vomit comet's," providing us first-hand with the chance to find out how NASA's big zero-g training aircraft got its name.

If the part of Jim Martin should be played by Robert Conrad, Ames neurosciences chief Mal Cohen also looks like he just walked in from Central Casting. In his herringbone blazer and Oxford shirt, with a pepper-and-salt beard, Cohen looks every bit the natty Stanford University professor and NASA research scientist that he is. Cohen greets us in the briefing room as Martin changes to his NASA flight suit. We're joined by co-pilot Casey Call, a tall drink of water who folds himself with difficulty into the tiny Learjet cockpit ("made for midgets," Martin quips).

We are slightly taken aback when we see up close just how tiny the Learjet is. Not exactly members of the frequent-flier club, we have a lot of empathy with microgravity experimenter Bob Welch, who later described himself as the type who much prefers to be in control. "I'm the kind," he says, "who never sleeps on a commercial flight just in case the pilot might want to consult me about something."

Now here we are, about to squeeze ourselves into a sleek and disarmingly small airplane sitting low on the runway. With a wingspan of 35 feet, 7 inches, a length of about 43 feet and a height at the tail not much over 12 feet, it's about the size of three sports cars bumper-to-bumper and about as high at the fuselage as the same cars stacked three deep.

Inside, the cramped cabin of the stripped-down jet is bristling with equipment for a lightning experiment NASA is currently running with the Air Force and Stanford Research Institute. The three of us arrange ourselves around it in the six-by-four space behind the cockpit, strapping a loose keyboard down with a bungee cord to make sure it survives the trip intact.

The roar of the Lear's two high-performance engines is deafening as the aircraft picks up speed on the runway. The Lear 24 was the first private corporate jet to be certified for civil transport, back in 1961, but it still is considered an experimental aircraft, and

can reach altitudes in the lower troposphere that compete (at lower cost) with the capabilities of the U-2. Today we won't be flying that high; but, as Paul Swearingen of the Lear Corporation told us, our test-pilot-caliber crew will otherwise be "pushing the envelope" in which the Lear 24 was originally certified to fly.

Watching the ground drop rapidly away from us, we grab a breath and double check our seatbelts. Below us the early morning traffic is still crawling along the freeway into Silicon Valley as we climb and then begin to level off, heading southwest toward the Pacific Coast. The noise continues to rumble through the cabin as the green hills and mountains begin to take on an unreal aspect, like cardboard cutouts lined up to give the illusion of three dimensions. Mountains, valleys, lakes, all laid out in a make-believe world below.

In the 15 years the Lear 24 has been part of the fleet at Ames, scientists have used it for a variety of research experiments ranging from infrared astronomy to acceleration display studies. Over the years, researchers in Ames' Life Science Division have made extensive use of the Lear to fly "parabolic" trajectories—a steep climb up a "hill," followed by a fall—that creates a state of weightlessness inside the cabin for a few seconds at a time. Among other projects, they've studied the effects of zero-g on the inner ear, flown test monkeys to be chosen for flight aboard Spacelab and tested various short-term adaptations to weightlessness.

Most recently, Cohen and "perceptual modification" expert Bob Welch have flown some 25 flights with human subjects to test adaptation of hand-eye coordination both to greater-than-normal gravity and to zero-g. In either case, the otoliths (small motion-sensing crystals) and the semicircular canals of the inner ear, which are calibrated to keep us in balance at normal Earth gravity, get thrown into a state of confusion. In addition, Cohen tells us, several factors throw off our judgment of where things are and how to reach them with our hands. That's what he and Welch are looking at, and the Learjet offers a relatively cheap and easy way to study what would otherwise take many flights aboard the much more expensive KC-135 or the space shuttle.

The only other way to experience zero-gravity, Cohen points out, is to free-fall from a tower or building. Using that technique, he adds dryly, "there aren't many people who've experienced more than three to four seconds of weightlessness and lived to tell about it."

What is it like to suddenly find yourself weightless in zero-g? Noisy, frightening at first, incredibly weird. And fun!

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Weightlessness 101: NASA exposes neophytes to zero-g inside a hollowed-out KC-135 aircraft (above).

Simulating the flight patterns used for Cohen and Welch's experiments, our trip includes several banks at 2 g, or double the Earth's normal gravity. The centrifugal force of the turning plane creates the added pull. But this is just "extra" 2 g experience to prepare us for what's to come.

We level off at about 12,000 feet and, speeding along at 360 knots, we begin to pull steeply upward in a change of flight path that puts us again under 2-2.5 g's until we reach a 45-to-50-degree nose-up attitude (an angle at which most planes don't normally fly, Martin comments to us mildly). Then the pilots cut back the throttle and "push over," traveling at a dramatically slowed 150 knots.

Inside the plane we hang suspended in the weightlessness of free fall for about 30 seconds as we fly a parabola across the sky, the plane's momentum still carrying it upward to an altitude of 17,000 feet, then coasting down the other side. "Just like when you toss something in the air, but not quite," according to Martin.

What is it like to suddenly find yourself weightless in zero-g? Noisy, frightening at first, incredibly weird. And fun! The problem is, in this case at least, "getting there" isn't half the fun. As it turns out, though, it is half the experiment. And that means struggling to orient yourself to a 2 g environment before the weightlessness sets in. Feeling your arms, head and body as something alien to you, a leaden suit that you have to drag laboriously through every slight body motion. Feeling your skin plastered tightly to your face, and an uncomfortable pressure on your eyeballs. Every muscle jerking and straining to rise up even three inches from your seat. Technically you're experiencing just a little more than what astronauts undergo during a shuttle reentry—just when they need to make precise decisions and perform landing operations. But with the muscle deconditioning that results from several days in space, Cohen estimates that shuttle travelers actually feel effects closer to the 8-9 g's pulled by jet test pilots.

And then you are at the hump, ready for the truly "out-of-this-world" experience of weightlessness. A moment of panic hits as you hear the engines throttle down, and for one brief instant you feel as if you are suddenly falling backwards. And then release—an incredible release that seems to stop time and motion and drop you into another dimension.

Cohen has told us it would feel something like scuba diving, but it doesn't. Underwater, you are aware that you are in a different environment. You feel the drag of the viscous substance around you, and you expect things to be different. Here in the airplane, surrounded by all these technological gizmos and by normally clothed humans, you shouldn't be floating in air. Objects shouldn't be suspended around you. The fountain pen in front of you shouldn't just stay there, floating like some magician's illusion when you let it go from your hand.

"Close your eyes, reach out and touch that rivet," Cohen instructs. "Then open your eyes and look what you've done." A quick movement toward where he was pointing, and you get your first lesson in zero-g perception: Your arm is a full six inches too high! Accustomed to the weight of gravity pulling against your muscles, you've used the same effort as always. But your arm has floated effortlessly upward as you reached out. You try a few times more, though, and find that you can adjust pretty quickly to the new rules.

And then it all starts to happen again as Cohen shouts out some more instructions to Martin. The Learjet begins another rollercoaster maneuver, moving back once again into that heavy, slow-motion stretch of 2 g time. Your body wears the lead suit again and you feel as if you're trying on someone else's face, and it doesn't fit properly. ▷

"Close your eyes again, reach out and touch the rivet," shouts Cohen, eager for you to see what happens. This time, your arm weighing twice as much as normal, you struggle against what feels like a blanket of lead. Again you open your eyes, this time to discover that all your struggle has still resulted in miscalculation. Although we don't experience it strongly now, Cohen tells us that at 2 g's there is also an effect called the "elevator illusion," which affects your vision, especially if you're looking at a single spot of light in dim surroundings. Test subjects still have trouble adjusting at 2 g, even after they get used to the weight of their own arm, because objects aren't located where they seem to be.

Martin levels out the plane again, and we head steeply upward once more into the heavy oppression of our climb up the hill of the parabola. Following Cohen's suggestions, we nod our heads vertically and lean them sideways toward our shoulders to feel the effects of 2 g on the inner ear. Tiny hair-like receptors inside our heads (angular and linear accelerometers, Cohen calls them) send off shrieking messages of confusion and rebellion that set waves of nausea pulsing though our bodies. Then we break free

Inside the plane we hang suspended in the weightlessness of free fall for about 30 seconds as we fly a parabola across the sky.

▼ ▼ ▼

again in the bliss of free-falling zero-g, only to plunge 30 seconds later into the blurring pressure of the downward ride.

In Cohen and Welch's experiments, they fly volunteers one by one on this aerial rollercoaster. Onboard is a device that, using a system of mirrors, appears to project a target on a touch-sensitive grid. While flying at zero-g or 2 g, the subjects touch the grid where it appears to them that the target is projected. Then the experimenters track the difference between what the subjects intend to do and what they actually do—and note the rate of adjustment.

Cohen and Welch hope to find out how long it takes people to recalibrate and adapt to transitions between zero-g and increments of normal gravity. Knowing this kind of data and training to accelerate the transition could be critical for astronauts who need to operate controls under similar conditions—when flying the shuttle, or on future journeys to Mars or the Moon.

We complete a total of four dizzying parabolas, about two full minutes of zero-g altogether. When Martin flew the KC-135, he'd told us beforehand, they typically flew 100 parabolas in a day's work. "One person who came with us turned green after four," he said. "You should have seen the look I got when I explained we had another 96 left to go." That routine even got to steely-eyed career Navy combat pilots like Apollo astronaut Ron Evans, he'd warned us.

So when it's time to head for home, it's little wonder we're ready. The tiny Lear turns north and begins to head up the rugged coastline. Martin and Call bring us in for a clean landing and taxi toward the Ames hangar. On the right, mechanics ready the C-141 for an infrared astronomy flight late that night. Nearby, an experimental tilt-rotor aircraft readies for takeoff.

As we're motioned into a spot near

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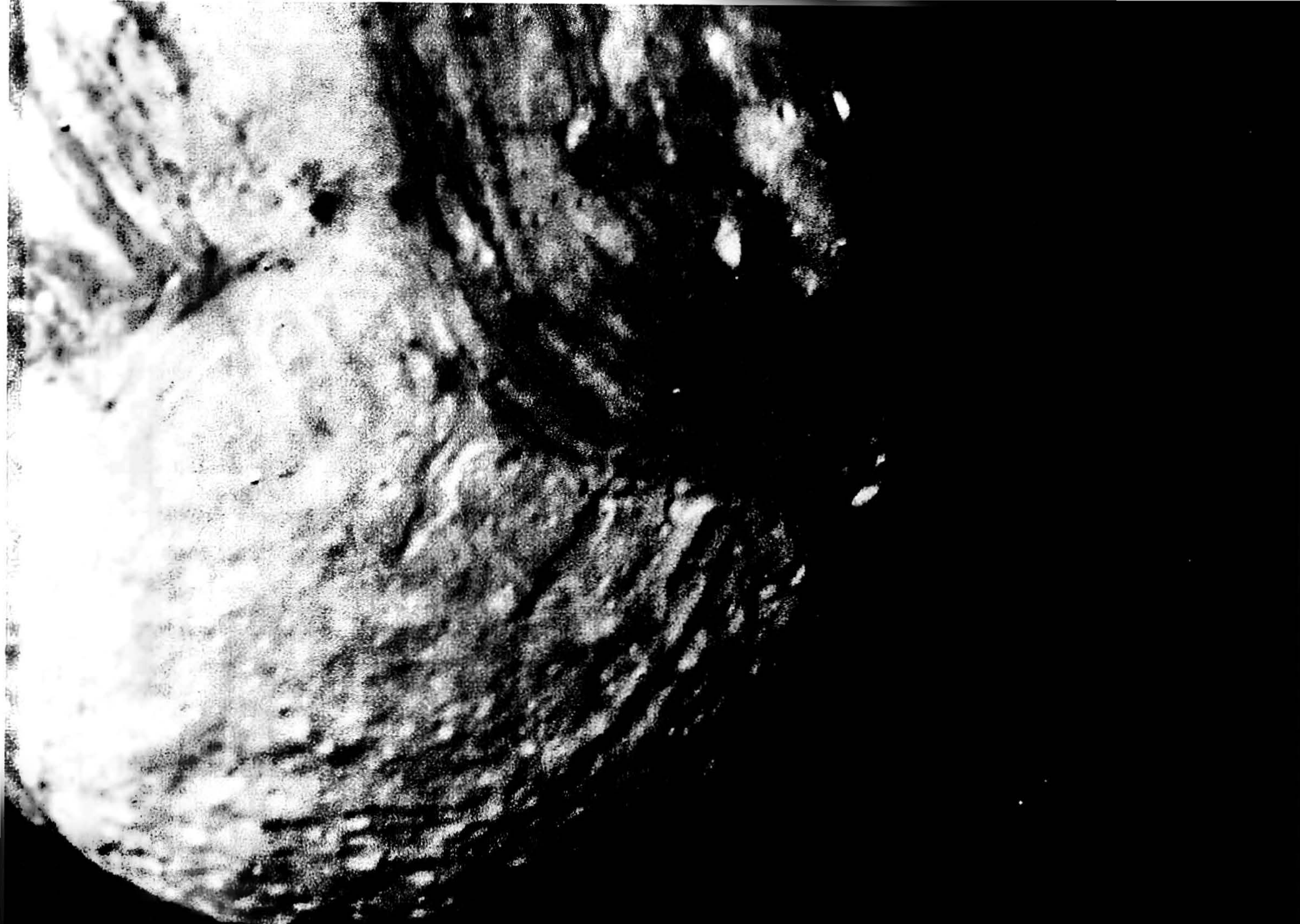

A DAY ON

MIRANDA

Where else could you take a flying leap off a ten mile-high cliff, and live to tell the tale?

No explorer has ever set foot on Miranda, no probe ever landed there. Until Voyager 2 passed through Uranus' neighborhood in 1986, no one had ever clearly seen the icy satellite's surface. But thanks to a handful of pictures returned by Voyager, we now know Miranda to be one of the strangest bodies in the Solar System, well worth a visit for the 21st century tourist who's become bored with Martian valleys and Saturnian rings.

Uranus is three times closer to tiny Miranda than we are to the surface of our own Moon, and Uranus is four times wider than the Earth. Even at half phase, the planet dominates the Mirandan sky, a turquoise ball of vapor whose dayside and nightside are bisected by rings so thin they give the impression of a spider's web in space. Auroral streamers blaze on the dark hemisphere. These are the last screams of electrons from the Sun, plunging down twisting magnetic field lines to collide with the Uranian atmosphere.

Standing on this 250 mile-wide ball of ice and rock, you weigh about 1/100th what you would weigh on Earth. So does everything around you, allowing you to perform Superman-like feats. You could, for example, heft an automobile-sized boulder over your head and toss it 100 feet into the airless sky. But don't try to catch it when it comes down, or you'll be in for a very hard lesson in the difference between weight and mass!

Though it weighs only 20 pounds, and would return to the ground at a mere five miles per hour, the boulder would scrunch down with all the bone-splitting force of a 2000-pound mass. (Imagine getting your foot caught between a dock and a powerboat mov-

BY CHARLES R. PELLEGRINO

ing at five miles per hour. Your foot would be crushed, yet if that boat were sitting in still water, you could easily kick it away. The same laws apply to tossing boulders on Miranda, or any other low-gravity world in the Solar System.)

What about walking and running—or rather, hopping? On the Moon, astronauts adjusted with surprising rapidity to the new rules. Within minutes of setting foot on the lunar surface, Apollo 11's Buzz Aldrin learned that ordinary walking is quite ineffective. He found that hopping about, like a child playing hopscotch, provided the best means of locomotion. Those who followed on subsequent missions followed his example.

On Miranda, this slow—very slow—bounding motion produces a wonderful sense of buoyancy. Even a modest kick sends you 30 feet into the sky, and you stay there fully 26 seconds, touching down at a mere 2.8 miles per hour. In a single bound, you may drift 200 feet from where you started, and you notice very quickly that your inertia is much greater than on Earth. Though you weigh barely two pounds in a space suit, you still carry the same mass that goes along with 200 Earth-pounds; your forward momentum is one hundred times as sluggish as it would be on Earth.

You can't simply sprint off in some direction and immediately zip along at ten feet per second. Even slow running speeds must be built up gradually, through many successive hops, which means that you need a runway ahead of you.

And when you decide to stop, remember that all your mass will still be trying to continue forward. On Miranda,

ALL PHOTOS U.S. GEOLOGICAL SURVEY/NASA

the laws of motion mechanics dictate that you use 20 or 30 steps to wind down to a stop. You can't simply come to a halt, like an Earth-bound runner. Try it and you'll topple face down into the Mirandan dust, skidding and bumping across the surface for a half-mile or more.

Of course, that information isn't terribly useful to you now that you're up to speed and less than 100 feet from the edge of the beautiful, bizarre feature astronomers call "Miranda Canyon," first seen by Voyager 2 in 1986. There's no turning back. You're now committed to a spectacular sky dive off the highest sheer cliff in the Solar System.

Next rest stop, ten miles. Straight down.

During the first three seconds of your jump, you fly thirty feet straight out from the cliff's edge, but barely two feet downward. There's plenty of time for sightseeing, to think about what you have just done, and where you are in the universe. At moments like this, when the adrenaline surges and the brain shifts into maximum overdrive, each second stretches to the outermost limits. The slow motion of Miranda compounds the effect a hundredfold. You seem to hang there, dropping only inches per second. You count to ten, yet you're still almost level with the top of the cliff, 100 feet behind you. Most of your motion is horizontal.

Finally, your downward velocity

Uranus' moon Miranda as it first appeared in Voyager TV pictures.

catches up with your outward speed. You are traveling at the end of a long arc. Three hundred feet out from the cliff face, you've dropped 140 feet during the first thirty seconds. As you look up, consider this: had you driven off that cliff at a mere 120 miles per hour, you could actually have gone into orbit around Miranda. And 120 mph is easily within the capability of that trusty space vehicle, a 1967 Dodge Dart with a slant-six engine. Of course, you'd have needed a few oxygen tanks to burn the gas, and to get the proper traction you'd have had to tie a garage-size boulder to the luggage rack.

One minute into your dive. You're falling at a lazy 13 miles per hour. The edge of the cliff is 600 feet behind you and nearly 600 feet overhead, framed by Uranus' impossibly narrow rings. The rings have always been a show stealer. Even when Voyager 2 shot through the Uranian system in January 1986, the spacecraft took 50 pictures of the rings, compared to only seven of Miranda.

It was our first glimpse of new worlds, yet much attention was diverted from them, and many details were missed. To planetary geologists, Saturn and Uranus and Neptune would be beautiful places, if it weren't for all those damned *rings*...

Two minutes. Nearly a half-mile down, velocity 26 miles per hour. Twelve hundred feet away, features on the canyon wall no longer appear to be standing still. Over there, something big, bigger than a house, left a splash mark on the wall. In this ageless, airless place, there is no telling when it happened. Perhaps millions of years ago, while dinosaurs still roamed across Montana, a chunk of ice was dislodged from the ledge above to gouge a hole in the cliff face. It didn't zap down and shatter like a meteor. It bounced with lazy speed, two minutes after it broke loose, then continued on. *Déja vu:* you're falling in a parallel trajectory, retracing the boulder's path.

Three minutes. You've fallen a mile, picking up speed to 40 miles per hour. The cliff face is a half mile behind you...and you think, what the hell is a ten mile-high cliff doing here in the first place? From satellite altitude you'd be able to see grooved terrain radiating from three distinct points of origin, much like ripples spreading from

MIRANDA'S MYSTERIOUS MAKEOVER

Over three billion years ago, *something* reorganized Miranda's interior, thrusting up enormous ripple formations and producing cracks that now put the Grand Canyon to shame. What could have caused such immense geological changes, yet left the tiny satellite intact?

"Miranda is one of the strangest worlds yet discovered," says Laurence Soderblom of the U.S. Geological Survey, a Voyager mission scientist. "It has barely enough gravitational strength to pull itself into a sphere. Yet its surface displays exotic terrains that would seem more appropriate on a once volcanically active world ten times its size."

According to Soderblom, we know by looking at the outer Uranian satellites that they suffered an intense bombardment sometime in their history, because there are many large craters (wider than 60 miles) scattered across their surfaces. We also know that the gravitational focusing of Uranus itself caused Miranda and the other inner satellites to be blasted by incoming objects with even greater frequency.

"Miranda was probably disrupted by at least one titanic asteroid collision that nearly blasted the moon apart," Soderblom says. "The scrambled pieces could then have resettled into a lumpy sphere. If the world had previously begun to differentiate (wherein rocky material sinks toward the core), and if some fragments settled upside down, then heavier rocky material moving again toward the bottom and plumes of lighter ice rising toward the surface could account for the terrain."

But the topography immediately adjacent to Miranda's ripples is very ancient and heavily cratered, and apparently was never so dramatically disturbed. An alternate theory proposed by Soderblom is that the radioactive decay of heavy ele-

stones tossed into a pond. Except that these ripples are more than 100 miles across, and appear to have frozen in mid-stride.

The canyon is at the edge of one of the ripples. The ground looks as if it was compressed as the ripple spread into ancient, heavily cratered terrain. Before the ripple stopped, internal compression apparently cracked the crust and thrust up towering cliffs. And what caused the ripples to form? Nobody is certain. Truly nobody.

Six minutes. The cliff edge is four miles above. About 3000 feet away, you notice a second splash mark from the boulder that dropped from the ledge, dropped so long ago. The gouge is deeper this time. Like you, it must have been falling at 80 miles per hour when it passed this way.

A minute passes. Then another, and another. At 117 miles per hour, now the cliff face is hurtling by. Everything is moving too fast, and the canyon floor is coming up at you like a giant flyswatter. Beneath your feet, new details come into view every second. That little crater beyond your left toe grows perceptibly, revealing that it, too, is full of little craters.

And the curve of this world is much sharper than the Earth's. If you stood on the bottom of the canyon, Miranda's horizon would be only a few hundred feet, not miles, away. Even at a height of one mile, most of the canyon floor

Close-up shots revealed a series of breathtakingly sheer cliffs (upper right) at least ten miles high.

Something big, bigger than a house, left a splash mark on the wall. In this ageless, airless place, there is no telling when it happened.

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curves away from you north and south, and more and more of the view is being eaten up by the horizon each passing second.

Speaking of passing seconds, in less than forty of them you'll cover that last mile and hit bottom at 120 miles per hour. (Where's a '67 Dart when you need one?)

Fortunately, your mass is only a fraction that of the Dart, and stopping is almost as easy as stepping on the brake. When you sky dive on airless Miranda, your parachute, or brake, is a backpack filled with ice balls. The backpack feeds them in rapid succession into a hand-held cannon, while your suit's tiny thrusters, barely more powerful than an ordinary garden hose, keep your feet aimed at the ground and prevent you from spinning. Ten, twenty, forty ice balls lance down. Eighteen hundred feet from the bottom, as high as the Toronto TV Tower, you can clearly distinguish splashes of dust on the canyon floor—the formation of forty new craters.

You fire off forty more rounds, and stop dead in the sky at 500 feet. A slow descent for sixty seconds, and you touch down at 12 miles per hour. Your old friend, the boulder that dug holes in the cliff face, lies on the horizon 300 feet away, exactly where it landed 100 million years ago or more. It's been undisturbed on the bed of Miranda Canyon ever since. Looking up—ten miles up—you can almost see your starting point. Exhilarating.

Your only worry now is the climb back. □

Charles Pellegrino is the author of several popular science books, most recently Her Name, Titanic. *He wrote on the oceans of the Solar System in the August issue.*

ments in Miranda's rock and ice (a fresh supply of very energetic, supernova-derived isotopes appears to have been injected into our Solar System at the time of formation) briefly drove large convection cells similar to those which experts believe sustain continental drift on Earth. In Miranda's case, however, most of the internal heat was radiated away into space as warm ice began to breach the surface, and the whole process stopped about 3 billion years ago.

Small moons, with their relatively large surface area-to- volume ratios, radiate heat faster than larger bodies. At Saturn, Enceladus (with a diameter of 310 miles) is caught in a gravitational tug-of-war between the giant planet and the moon next door. So much frictional heat is dumped into Enceladus that convection still seems to occur; an icy ring in the satellite's orbit suggests that volcanoes are venting water into space.

But gravitational tugs don't seem to account for the reworking of Miranda. Heating has not been sustained at a constant rate for millions of years. It appears to have occurred instead as a single, short-lived pulse after the moon formed, and it seems to have been felt through the entire Uranian system.

So the mystery deepens. We can only speculate about what tore up the Uranian moons, threw Uranus onto its side (Uranus' north pole presently faces the Sun) and, farther afield, produced the utterly chaotic orbits of the Neptune and Pluto systems. Voyager 2 gave us only a handful of pictures with which to understand a hundred new questions—most of them raised by those pictures! Something fascinating, and perhaps very violent, happened out there; but with no future space missions slated for Uranus, we'll have to make do with those few tantalizing images for a very long time. □

Atla

Atlas IIA, General Dynamics' new 6,000-pound class launch vehicle, has just opened up a new option for doing business in space.

This commercial derivative of the Atlas II, recently selected as the U.S. Air Force's new medium launch vehicle, is now available in a cost-effective package that includes complete launch services. Scheduling is flexible to meet your needs, and we will start flying as early as 1991.

Reliable Atlas launch vehicles have been putting government and

NASA
TFNG

Rick Hauck, first of the "Thirty-Five New Guys" to reach space, shows off his class spirit during a training flight.

TEN YEARS AFTER

Most of the members of NASA's "Class of '78" are still astronauts. Some have gone on to other jobs. And a few have died.

BY ALCESTIS R. OBERG

As the new astronauts mounted the huge stage of the Johnson Space Center auditorium that hot July day in 1978, the space program seemed, briefly, to be reborn, its vigor and enthusiasm renewed.

They were the first astronaut class in nearly a decade, and the competition among the 10,000 people who applied had been very stiff. What emerged from the selection process was the cream of our youth, the future of America: Bright, healthy, attractive, nice. Most of the '78 class had master's degrees, and almost half had doctorates or M.D.'s. Many of the flyers were decorated war veterans; several were top-drawer test pilots. And ten of the 35 new astronauts were women or minorities, giving the class a new look and a new spirit.

Later, this rosy picture would be clouded by rumors of a behind-the-scenes tussle between NASA Headquarters and the Johnson Space Center honchos who had overseen the final selection several months earlier—a tussle that resulted in five white male pilots being dropped from the preliminary list of new astronauts so that five more mission specialists, four of whom were women, could be added.

But at the time, the press—and the whole nation—were charmed, fascinated in the way they had been with the Original Seven Mercury astronauts. In the best overview article of the time, Thomas O'Toole of the *Washington Post* baptized them the "Thirty Five New Guys," and the acronym "TFNG" was adopted by the group as their label. Judy Resnik had a logo fashioned for the TFNGs that appeared on their class t-shirts and posters: it showed astronauts stuffed into and crawling onto a shuttle orbiter with the motto, "We deliver."

The TFNGs had a few misconceptions about the astronaut job. "I didn't anticipate anyone dying," said Guion Bluford. "We work very hard to make the program safe—in fact, the primary effort is safety."

"We knew that some astronauts had died and also that we were going to spend time in jets," said Jeff Hoffman. "But if you had asked me then if I had *expected* any of us to die, I would have said no. There's a subtle difference between the idea that somebody *might* die and expecting that someone *would* die. It's not like going to war, where you expect people to die."

Others in the class of '78 had less abstract, less general feelings about death: "Someone sent me 35 souvenir envelopes in 1979, each with a picture of someone in my class on it," said John Fabian. "I remember thinking at the time, 'I better get these auto-

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The STS-26 crew (above) includes three TFNGs: Hauck, "Pinky" Nelson (second from left) and Dick Covey (far right). The Class of '78 was the first to break through boundaries of race and gender. Above right: Rhea Seddon and Ron McNair training for weightlessness. Opposite page, left to right: McNair, Guy Bluford, Fred Gregory, Seddon, Kathy Sullivan, Judy Resnik, Sally Ride, Anna Fisher and Shannon Lucid.

graphed now, because the day will come when some of these folks won't be here'."

The single most common misperception among the new recruits was that they would fly in space once or twice a year. The true flight rate turned out to be once or twice in *ten* years. Also, the astronaut job was less active than some had expected. "What impresses you are the facilities, and you get the idea that people spend all their time in simulators or flying planes, or in underwater training—things you can see," said Jeff Hoffman. "You never appreciate—no matter how often people tell you—how much time you spend sitting at your desk."

Still, the astronauts unanimously remember their first few years in the astronaut corps as exciting—a time of personal growth and expansion: "Our astronaut class was so large, they split us into morning and afternoon classes: the red group and blue group," recalled Dan Brandenstein, now Chief of the Astronaut Office. "The courses in astronomy, geology, oceanography—all the things I would have liked to know but didn't have the time to pursue—were real interesting. In fact, I was pleasantly surprised at how interesting the job was, even when I wasn't flying."

"The work prior to the flight of STS-1 (the first shuttle flight) was very exciting," said Hoffman. "It was still a big step into the unknown. Nobody knew how the shuttle was going to fly, so we were very involved in testing and developing the systems, learning how it was going to fly and discovering new things."

Many found it fascinating to go to work with their heroes, the older astronauts, some of whom were legendary aviators or spacefarers who had walked on the Moon. The youngsters listened with rapt attention when the veteran astronauts recalled the problems they had encountered on their historic voyages and the means they had used to overcome them.

The *esprit de corps* among the TFNGs was intense during the initial training period. They studied together, worked together and partied together. After the candidacy period, however, the class was split up and mixed in with the rest of the astronauts. The rookies were integrated into crews and into their technical tasks, and many had to travel out-of-town frequently— all of which made it hard to get together and stay together.

Nonetheless, some TFNGs clustered into associations that became enduring friendships. Sally Ride, John Fabian and Judy Resnik had a kinship based on their common involvement in developing the shuttle arm, or Remote Manipulator System. Terry Hart and Steve Nagel shared an office, a friendship and a birthday. "I was three hours older than Steve," Hart reminisced, "so I always joked about my greater age and maturity." Some crews still get together to celebrate the anniversary of their flights.

In June 1983, the first of the '78 class—Rick Hauck, John Fabian, Sally Ride and Norm Thagard—flew aboard Challenger on the seventh shuttle flight. At the preflight press conference, Sally Ride said she was happier about having an early flight than at being named America's first woman in space. It was a perfectly typical astronaut's response, although it

caused some feminists to clench their teeth. The press attention to that flight was so intense that her crewmate John Fabian used to joke: "To get your picture taken, all you have to do is stand next to Sally."

Many other firsts followed in quick succession. Guion Bluford, the first black American astronaut, flew on the next flight along with two other TFNGs, Dan Brandenstein and Dale Gardner, who experienced the first night launch and night landing of a shuttle. Brewster Shaw co-piloted Columbia on the following Spacelab 1 flight, with the first international crew on an American mission since Apollo-Soyuz. Ellison Onizuka, the first Asian-American astronaut, flew aboard the first (and very publicity-shy) top-secret military flight. He remarked with dry humor just before his launch: "I don't think they picked me for this flight because I'm the first oriental."

In the years that followed, there were more exciting flights: the dramatic repair of the Solar Max satellite, the skillful retrieval of the mislaunched Westar and Palapa satellites, the inspiring tests of the rocket-powered backpacks, the hectic experimentation of the four Spacelab flights.

The TFNGs sometimes had to perform their jobs with great precision, as when Anna Fisher deftly guided the shuttle's robot arm in the rescue of the Westar and Palapa satellites. And sometimes they had to improvise solutions to unexpected problems, as Rhea Seddon did in fashioning a "flyswatter" device to activate the power system on a malfunctioning Syncom satellite.

▷

LIFE AFTER NASA

Although some people would think being an astronaut is the ultimate job, there are some things ex-astronauts don't miss about it.

James van Hoften could summarize what he doesn't miss in one word: Houston. "I'm from the San Francisco Bay area, and I love it here. When Pinky Nelson and Dick Covey visited me, they kept asking me how often the weather was this nice. It's *usually* like that."

"I don't miss the overnight simulations," said Terry Hart, "and what seemed to be the endless meetings."

"NASA was the only place I've been where you can go into meetings at eight in the morning and still be in the same meeting at eight that night," agreed John Fabian. "They wait for everybody to give up so nobody has to make a decision. They just meet until they get a consensus, or until nobody objects anymore. Then they adjourn."

"I've been to long meetings outside NASA," said van Hoften, "but they really decide something in them. On the outside, everybody has to produce. They can't just sit and watch, like in the government."

Many of those outside NASA feel happy about the better salaries and greater job opportunities.

"I love being a general," said Bob Stewart, who returned to the Army after leaving NASA. "We're doing great research here. Too bad I can't talk about it. It would knock your socks off."

"We have junior engineers here that get paid more than most of the astronauts," said van Hoften, now at Bechtel, the large construction firm. "The astronauts even had to get their own insurance. One insurance company wanted me to pay an $800 premium for one week of spaceflight coverage. I didn't like the odds. Besides that, NASA tended to treat the astronauts like pawns in the organization."

"Some astronauts feel they don't know what would be waiting for them outside NASA in some virgin territory where they'd have to start over again," said van Hoften. "But they're all such incredible overachievers. They'd find the world would be waiting with open arms to take people who have done the kinds of things they've done."

Sally Ride, meanwhile, has sought an escape from her overwhelming celebrity, and may even have found it. "The people handling her publicity," confided one NASA public affairs official, "are very effective at turning down interview requests." □

Other missions were much less thrilling, involving only the routine launch of commercial satellites, medical tests and Earth observations. A few flights, involving spaceflight's first "tourists"—politicians, foreign dignitaries, corporate representatives—were irksome. "My second flight, 51-G, was not as much fun as my first," John Fabian said candidly. "The larger crew and the international flavor brought additional pressures. Foreign dignitaries go home as national heroes, and you have to document all that and make sure their experiments are successful, even if they are not that meaningful."

Dick Covey was the last of the '78 class to fly for the first time, in August 1985. Every single person in the class had flown in space and returned safely to Earth between 1983 and 1985. "It's a tribute to the selection process and the steadiness of the program that we all did," said Terry Hart.

But through the 1980's, NASA had begun to change the shuttle program in a subtle way, and by extension, the astronaut job itself. The space agency's diminishing commitment and funding for dedicated shuttle science flights left the scientist-astronauts' position ill-defined, lacking in strong purpose. As NASA selected more astronauts in 1984, 1985 and 1987, the queue waiting for a spaceflight became very long. The astronaut job involved less flying in space, and more tedious technical work and support for the flights of others.

With little, if any, career progression track or goal beyond working years to get a few more days in space, some astronauts admitted the existence of "burn-out." After their second or third space flight, many astronauts found that the gloss was off the job. In seven years, two dozen of the nearly 100 NASA astronauts have left the agency, six of them TFNGs.

Terry Hart's mid-1984 decision to go back to his former employer, Bell Labs, soon after his first and only flight, was hurried by the government-forced Bell System divestiture. John Fabian left in late 1985 "because my wife, Donna, said two flights were enough for her, and she hoped they were enough for me." His next assignment would have been the launch of the Jupiter-bound Galileo probe with its attached Centaur rocket, a payload the astronauts used to call "the flying bomb" (due to uncertainties about the new liquid-fueled booster's performance) and then-chief astronaut John Young referred to as "the Death Star."

When Challenger blew up on January 28, 1986, four of the '78 class—Dick Scobee, Judy Resnik, Ellison Onizuka and Ron McNair died, along with Mike Smith of the class of 1980, who had had many friends among his 1978 peers.

"We took it hard," recalled Bluford. "These are the people we came in with, trained with, partied with, worked with, whose flights we supported and who supported our flights."

For the astronauts, one sad duty followed another for the rest of 1986: helping the families overcome their loss, attending the emotionally wrenching national memorial service, investigating the accident that took the lives of their friends, following the recovered last remains to final burial. Press coverage of NASA became shrill and critical. Support for the space agency and its programs waned in the Administration and in Congress.

The aftermath of the Challenger disaster left the remaining members of the '78 class shaken, demoralized and angry. Sally Ride and John Fabian worked together closely on the Rogers Commission investigating the accident that killed their friend Judy Resnik. "I was aware of safety problems before the accident," said Fabian. "There were things we had doubts about as crew members. But it was not until we were part way through the investigation that I realized it was an institutional problem. The higher up you went in NASA, the more people thought it (the shuttle) was a DC-9. They thought they could operate it like United or Eastern. The safety program failed completely."

As the investigation wound down, everybody realized it would be years before the shuttle would return to flight status—and then at a greatly reduced flight rate. Real professional malaise began to set in, and four of the '78 class left the astronaut corps. Dale Gardner and Robert Stewart, both military officers, accepted prominent reassignments; Stewart was promoted to general. Sally Ride took an academic research post at Stanford University and James van Hoften a lucrative, interesting job in private industry.

"I don't think the program is properly set up as a career," said van Hoften. "There's no upward mobility. With so many astronauts, there aren't going to be many chances to fly. I find that a lot of the astronaut work is not what I consider very major contributions. I enjoyed it while I was there, but it was time for me to move on. I was at the right age where I could make a second career."

For a few TFNGs, there was some upward movement. Dan Brandenstein was promoted to chief of the Astronaut Office and Steve Hawley, an astronomer and the ex-husband of Sally Ride, became deputy chief. Rick Hauck, Dick Covey and George "Pinky" Nelson were assigned to the first post-Challenger flight. Others say they sincerely enjoy the technical development work, and don't mind the long wait for a spaceflight.

Many friendships have endured over the years among the group. There have been a few "Class of '78" reunions this year and plenty to reminisce about. The men and women selected in '78 and '80 are considered by many outside NASA to be the high water mark of talent in astronaut classes, unequaled before or since. Most '78 astronauts are proud of the great diversity of background, talent, education and experience in their class, and consider those qualities to be their prime contribution to the astronaut profession. "We formed the backbone of the shuttle program," said van Hoften.

"We brought down barriers," emphasized Guion Bluford, "and created opportunities for others." The diverse group of women— some of them wives and mothers—proved beyond doubt that a woman could fulfill any role in society she chooses, and still be a thoroughly professional astronaut.

"We'll be remembered as the Class of Sally Ride," quipped Fabian—and added: "She'd hate that I said that."

With the TFNGs, non-pilot scientists and engineers were given a more prominent role in spaceflight than ever before. "We gave NASA more cohesion because we supported so many far-flung activities," said Terry Hart. "We lubricated the process, made NASA work better."

Although no members of the Class of '78 are likely to be on the great voyages of the future to the Moon or Mars, their most significant contribution may be the way they changed the archetype of the astronaut from the "right stuff" egotistical lone warrior to the team player and crew member—an archetype befitting a more mature technology and another spaceflight era. They view themselves not as heroes, but as members of a highly skilled technical team whose weaknesses are compensated by others' strengths, and whose strengths buttress up others' deficiencies to unite against the only significant human barrier: the unknown. □

Alcestis Oberg is the author (with James Oberg) of Pioneering Space: Living on the Next Frontier. *Her articles on space have appeared in many magazines and newspapers, and she was a semifinalist in NASA's Journalist-in-Space competition.*

THE BIG THREE OPEN SHOP

TOM USCIAK

MARK USCIAK

MARTIN MARIETTA

U.S. rocket companies line up their customers, straighten out their insurance and sweat out the oxidizer shortage.

BY THOMAS O'TOOLE

Remember when Pan American Airways began taking reservations for trips to the Moon? Or when a New York real estate tycoon sold deeds to lunar real estate, while a California developer did the same thing for a small valley on Mars?

As feeble and fanciful as they might seem today, these false starts were still the first steps taken by American business to commercialize space. Done half in jest and forgotten almost as quickly as they started, they nonetheless set the stage for what is happening now: A private American space launch industry that didn't even exist two years ago has signed contracts worth almost $1 billion to carry 18 payloads into space through 1992.

This thriving commercial business adds 8,000 jobs to the American economy and offsets the nation's trade deficit by $660 million. What's more, the companies involved in these ventures are negotiating at least ten additional launch licenses, worth another $600 million, that will carry them into 1994 or 1995. The commercialization of space has indeed begun.

Titan 4 rockets take shape at a Martin Marietta plant near Denver.

"In terms of getting a foot in the door to this new business, I'd have to say the door's been kicked wide open," said Transportation Secretary Jim Burnley, whose department has been given the task of licensing and regulating the fledgling commercial space transportation industry. "The commercial launch sector may well be the most active part of America's non-military space program for the next several years."

How did an industry get so big and so busy in two short years? The tragedy of the Challenger explosion in January 1986 had a lot to do with it. In an abrupt change of policy, President Reagan ordered the National Aeronautics and Space Administration out of the business of launching commercial satellites, except for those designed specifically to go on the shuttle.

Into the vacuum stepped the Big Three corporations of the United States rocket industry: McDonnell Douglas, General Dynamics and Martin Marietta. At the time of the Challenger accident, each of these firms was planning to close down its rocket launcher production line. Not any more. All three production lines are up and humming, once more producing the Delta, Atlas and Titan launch vehicles that were the backbone of the U.S. rocket business before the space shuttle started flying.

The first scheduled flight of the new commercial manifest is set for March 1989, using a Delta rocket built by McDonnell Douglas to carry a communications satellite into orbit for the government of India. Next comes the double launch in August 1989 of a Japanese and a British satellite on a Martin Marietta Titan, followed in September by a U.S. Navy satellite on top of a General Dynamics Atlas.

Two more launches are scheduled for 1989, one an Intelsat 6 communications satellite on a Titan and the other an INMARSAT maritime satellite on a Delta. Eight launches are set for 1990, two for 1991 and one for 1992. Seven flights are for the U.S. government, four for international consortiums, three for the British and one apiece for Japan, Indonesia, India and a European combine.

Most interesting is the way America's Big Three has held its own in the competition with the European Space Agency's Ariane rocket launcher for the available international business. So far, the scorecard reads 13 new launch commitments for the U.S. and just two for Ariane, despite the fact that the U.S. government refuses to subsidize the American rocket companies to bring their launch prices more in line with Ariane's.

"That's one of the best things about this manifest," boasts Transportation Secretary Burnley. "When you look at these numbers, it's not necessary to even talk about U.S. subsidies for launch services."

That's how it stands now. Things could change dramatically, however, if U.S. launchers suffer a run of accidents, or if the foreign competition heats up the way it promises to do. Right now ESA's Ariane is the serious competition, but the experts in the business don't discount growing competition from the Soviet Union as well as from space-age upstarts like Japan, China, India, Sweden and Australia. The U.S. Commerce Department has identified no fewer than 13 countries around the world pondering entry into the rocket launching business.

Not all of these nations are likely to force their way into the business. Japan, for example, is an island nation where launches are restricted to certain times of year so as not to interfere with the offshore fishing industry. What about China? Commercial versions of the Long March launch vehicle have yet to establish a track record, but China has an advantage few capitalist countries have. It doesn't have to turn a profit on a launch.

Consider China's approach in selling its Long March line of launchers to the rest of the world. The Chinese are quoting a launch price of $20 million for one version of the Long March. The equivalent Titan marketed by Martin Marietta carries a price tag of almost $100 million.

What U.S. rocket launchers have going for them are reliability and liftoff power. The Titan 3, for example, has succeeded in 130 out of 135 launches. Due to fly late this year for the first time, the Titan 4 and Titan 4 Centaur will soon be the biggest boosters in the U.S. fleet, able to place 10,000 pounds in a communications satellite-type orbit, 32,000 pounds in polar orbit and 29,000 pounds in a low orbit inclined 28.6 degrees to the equator. That's almost as much as the space shuttle can haul upstairs.

The potential spoilsport in all of this is a conceivable shortage of solid rocket fuel brought on by the explosion last May that destroyed a chemical plant in Henderson, Nevada. That single plant manufactured most of the ammonium perchlorate oxidizer—the material that allows solid fuel to burn—consumed by U.S. rocket makers. Almost all the configurations of the Delta and Titan launch vehicles use solid-fueled strap-on rockets for liftoff assist, so it is possible that the U.S. could run out of solid rocket fuel before the Nevada plant is rebuilt or replaced.

The Air Force says it has enough oxidizer for two years of scheduled launches. But what about the launches that don't involve the Air Force?

"Obviously, we've got a problem," admits Transportation Secretary Burnley. "There is some surplus fuel in Italy and some in Japan and some in storage here in the United States. The issue is one of allocation, which I believe can be handled without hardship to commercial customers."

But the two-year-old commercial space launch industry has hurdled more difficult obstacles than a shortage of rocket propellant. There was Air Force reluctance to let private industry use its Cape Canaveral launch pads to boost foreign and commercial satellites into orbit. That was Hurdle One, which was cleared early this year when the Air Force signed agreements with the Big Three to use its pads.

The liability hurdles still exist. What if a commercial rocket flies out of control leaving Cape Canaveral and hits Miami Beach instead of climbing into orbit? Who pays? The industry is not protected against third party liability claims that exceed insurance coverage in a catastrophic accident. Slowly but surely, a compromise is being reached that may settle this critical issue. Already, the government has agreed to accept liability if a federal launch pad worker contributes to an accident by acting in a "reckless and wanton" manner at launch time.

Most experts agree that the commercial space launch business has a bright future. The Commerce Department estimates that by the year 2000, private rocket launchers will be taking 25 satellites a year into Earth orbit for between $60 million and $70 million a shot, which crunches out to as much as $1.7 billion a year.

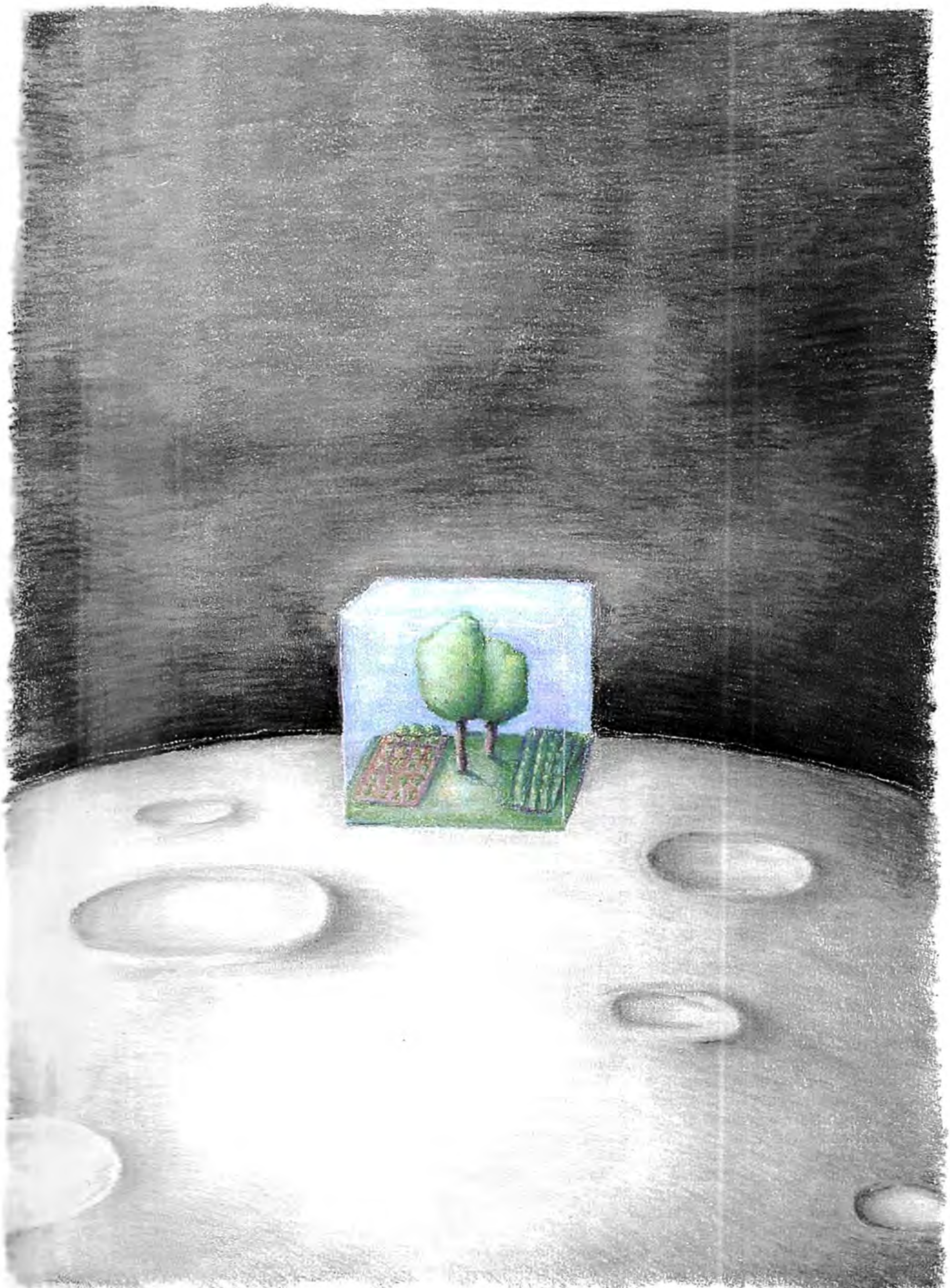
Commerce officials figure the communications satellite business will level off because of competition from underwater fiber-optic cables, but also figures that remote sensing satellites that scan the Earth for mineral deposits and signs of pollution will more than make up for the loss. Commerce estimates the worldwide remote sensing market at $7.2 billion to $9 billion for the 10 years ending in 1997.

"There are big places on Earth," says one expert, "places like South America, Australia, New Zealand, China and Africa that have still not been touched by remote sensing."

And that could mean Big Bucks for the Big Three. □

Thomas O'Toole covered the space program for The Washington Post *for 20 years, and is a past winner of the National Space Club Press Award.*

Transportation Secretary Jim Burnley: "In terms of getting a foot in the door to this new business, I'd have to say the door's been kicked wide open."



RICK PETERSON

"Then God said,
'Let the Earth sprout vegetation,
plants yielding seed,
and fruit trees bearing fruit after their kind,
with seed in them, on the Earth;'
and it was so."

–Genesis 1:11,
New American Standard Bible

NASA'S LITTLE ACRE

Space travelers of the future will need to grow their own.

BY BETH DICKEY

If only the scientists trying to create a world for us in outer space had it so easy. God had Earth's photosynthetic generator up and running in three days, according to the Bible. But it may be three decades before a globe full of engineers, plant physiologists and soil chemists can say they've figured out how He did it.

The researchers' goal is to create an environment where plants recycle air, water and fertilizers to produce food, just like on Earth. Their Eden would be a closed ecological life support system–or CELSS, in NASA lingo–in which computers control nature. And their ultimate purpose is to make humans self-sufficient inside an orbiting space station, a lunar base or a spaceship on its way to Mars.

"If God did it once, we should be able to do it again," contends William Knott, a plant physiologist at NASA's Kennedy Space Center in Florida.

Like most experts, Knott thinks it will be too costly in the case of a space station or a Moon colony, and nearly impossible in the case of a Mars mission, to keep a crew supplied with fresh air, clean water and food from Earth. He and his colleagues believe a closed system will be more economical than sending the necessities to Earth orbit. And they're sure CELSS will be the only way to provide life's essentials during a multi-year, multi-million-mile mission to Mars.

"If you're truly, permanently going to space, even if it's 300 years from now, you've got to have a system like this," Knott insists. Scientists will argue about how to create a CELSS until they're calling each other names–but on this point, they all agree with NASA agricultural engineer John Sager: "Sooner or later, we're going to get tired of sending TV dinners out and bringing port-a-potties back."

Sager, who studied plant productivity for the Smithsonian Institution before he started designing CELSS equipment for Knott two years ago, is among those who are afraid the survival kit won't be ready in time for our trek across the starry frontier. Sager, Knott and others blame tight budgets and poor research coordination for their fears.

No single visionary is guiding the project's destiny, they point out. Some crucial parts of CELSS–such as the system that must transform human waste into a safe fertilizer for plants–aren't being researched in the United States, the scientists charge, because federal budgets are spread so thinly.

Each year, three NASA field centers–Kennedy Space Center, Johnson Space Center in Texas and Ames Research Center in California–share a few million research dollars with about a dozen colleges and universities. Ralph Prince, whose CELSS sketches are blossoming into Knott's working prototype, guesses we'll spend billions of dollars developing a reliable long-term life support system, learning how to cram the important parts of a biosphere into a container small enough to fit inside a spacecraft or an extraterrestrial greenhouse.

Right now, NASA's experimental CELSS container is an old pressure chamber Bill Knott saved from a pile of Apollo-era junk a few years ago. Knott placed the chamber near the back door of a hangar on Cape Canaveral Air Force Station, a few miles across the Banana River from Kennedy Space Center. He and a small group of researchers from government, industry and academia added valves, tubes, racks, lamps and monitors, and called it a biomass production chamber. Now they're trying to grow wheat inside the sealed container.

An airlock separates the bright, dry stillness inside the chamber from the humid, fishy-smelling draft of "Hangar L". Each day, garbed in sterile coats and hats and masks and gloves, a couple of workers–there's no room for more–tend the tiny field of wheat that sprouts from 64 trapezoidal slotted trays behind the airlock.

Because of its limited size and weight, a CELSS in flight might carry only a handful of staple crops–including wheat, rice, beans, soy, potatoes, peanuts and lettuce. It might carry only 25 gallons of water. On Earth, that's barely enough to get a crew of six through its morning routine. The crew will use and reuse the same water for drinking, cooking, flushing toilets and irrigating plants. From seven or eight crops, they'll cook breakfast, lunch and dinner. So Prince, Sager, Knott and their colleagues are searching for ways to recycle that water in a matter of seconds, and to assure optimum crop

yield day in and day out.

But it takes time to make the leap from picnic baskets to cosmic kitchens. Two years ago, Knott predicted a CELSS would be ready for a test flight as early as the turn of the century. Today, Prince predicts it won't be ready before 2020.

"Going from unmanned rockets to manned spacecraft was a major step," Prince points out, "but nothing compares to going from carrying your own food to growing your own food."

Scientists currently are looking at two possible media for plant growth: hydroponics, and the native soil that settlers will find on the Moon and Mars. Hydroponics uses a solution of nutrients circulating continuously around the roots instead of soil—a technique that was developed in the late 1930s. It wasn't until the 1970s that the Apollo and Viking missions brought within reach the idea of cultivating crops in lunar or Martian soil, fortified with fertilizers.

With their 40-year head start, agronomists using hydroponics and aeroponics—a related root-misting technique—have learned to produce "two to five times the edible yield in a controlled environment that you can out in Mother Nature," Sager notes, "because you reduce the stress and provide more optimal conditions." While biologists are fine-tuning their already proven techniques, soil chemists are breaking new ground, trying to simulate lunar and Martian dirt.

The major research is confined to terrestrial laboratories, but crews aboard numerous American space shuttle and Soviet space station missions have conducted controlled-environment plant-growth experiments.

Before the Challenger explosion in January 1986, every space shuttle mission but the first one had carried some sort of experiment intended to study how weightlessness affects the genes and germination of plant seedlings. Most of the studies were designed and sponsored by the research departments of high schools and colleges in the United States, West Germany, France and Mexico.

Equipment problems prevented several of the experiments from being conducted in orbit. Others—trapped aboard the Long-Duration Exposure Facility launched from the shuttle in 1984 and still waiting to be retrieved—are believed ruined. NASA has published the results of some shuttle studies, but those wilt alongside the experience gained by Soviets with salad crops and flowers aboard Salyut 6 in the late 1970s and early 1980s.

According to a 1984 report by the Congressional Research Service, Soviet cosmonauts conducted quite a menu of biological experiments on the Salyut 6 space station and set the table for even juicier results on Salyut 7, launched in 1982.

Like the United States, the Soviet Union wants to support life in space using a CELSS in which plants grow on human waste, produce oxygen and supply a balanced diet in the process. Soviet scientists have done it on Earth, according to the Congressional report, but with a system too big and heavy to place in orbit.

The researchers' Eden would be a closed ecological life support system—or CELSS, in NASA lingo—in which computers control nature.

A sampler of both nations' space-based research:

- On the third space shuttle flight in March 1982 and again during the Spacelab 2 mission in mid-1985, University of Houston researchers discovered that light can't always substitute for gravity in determining the orientation of growing plants. Oats, mung beans and pine seedlings grew at off angles, away from the light and away from their growth medium.
- The Park Seed Company of Greenwood, South Carolina sent more than 40 kinds of fruit and vegetable seeds into orbit inside a canister aboard the sixth shuttle flight in April 1983. Some seeds were sealed in airtight bags while others were exposed. Uncovered pea and potato seeds germinated better than their ground-based counterparts, the experimenters found.
- Cosmonauts have grown cucumbers, onions, radishes, dill, parsley, garlic fennel, lettuce, and mushrooms—"really strange mushrooms... with curly stems," according to TASS, the Soviet news agency. But few plants survived, and those that did didn't produce seeds for another season.
- The Soyuz 35/37 crew used an apparatus called "Malakhit" to grow orchids and other plants in space. The automatic space garden provided light and regenerated water to the plants and took time-lapse photographs as they grew. Flowering orchids were carried aboard Salyut 6, but the petals fell off immediately. The experiment was repeated, with the same result. In another orchid ordeal, the plants did not flower in space—although they developed normally for nearly six months.
- A tulip bud brought "a breath of spring" to the Soyuz 32/34 crew aboard Salyut 6 in May 1979. Two months later TASS reported that tulips in space produced a half-meter shoot, but that their buds didn't open (analysts at the Congressional Research Service were unsure whether the news agency was referring to this particular tulip or others that might have been on board, but stated, "What is obvious is that the plants were not behaving in the expected manner.") Later, according to TASS, Soviet scientists were trying to find out "why plants in outer space do not blossom and bear fruit."

Might the lack of gravity have something to do with it? Weightlessness limits photosynthesis. Without gravity, water just hangs around—literally. Perhaps, as a result, plants are poisoned by or drown in their own waste. Whatever the answer, it's a question that keeps American scientists scratching their heads—and arguing among themselves about whose technique is best.

Privately, many of these scientists admit they really don't know which system—hydroponics or growing plants in native lunar or Martian soil—would be better for keeping humans alive in space. But they do have their opinions about the merits of each method.

"We think it's pretty crazy to use lunar soil, because we have so much better control (with hydroponics). We don't use soil on Earth because we can do it better this way," says Frank Salisbury, a Utah State University scientist whose experiments with hydroponics in the early 1980s broke the world's record for

producing the most amount of edible wheat per square meter per day. "I have strong doubts you could get oxygen and nutrients to the roots as efficiently, particularly on the Moon where the gravity is one-sixth," says Salisbury.

G. William Easterwood, a geochemist now working at Florida's Walt Disney World to investigate how plants grow in simulated lunar soil, disagrees. He thinks the Moon would make a fine garden.

"I think the lunar material could grow any damn thing. Plants tend to do well in dirt," retorts Easterwood, who grows healthy wheat and soybeans in pseudo-lunar soil at Disney's EPCOT Center. "The Land," an EPCOT attraction, displays the fruit of his effort.

"You add nutrients to the hydroponic system. In a soil system, that would work, too," Easterwood asserts. And he's apparently proven his theory. Easterwood potted crops in ground basalt, a volcanic rock whose nutrient-free chemical composition most resembles that of the Moon. By tending the plants with nitrogen, phosphorus and potassium fertilizers, Easterwood actually created a clay suitable for plant growth.

"On a lunar base, you will be using a regolith [loose rock and soil] to obtain your oxygen, to obtain your water, to process different materials, as a radiation shield, probably to derive fertilizers from. And if you can do all that, I don't see why you can't use it as a substrate for plant growth," he contends.

Easterwood wants to get his hands on an actual sample of Moon dirt to investigate whether added nutrients could react with the soil to form heavy metals that are poisonous to the plants or the people. In spite of that fear, Easterwood is confident that a soil-based system is safer.

"If a drastic chemical or environmental change happened in a soil system, it has a buffering capacity that could reduce the problem," he points out. "In a hydroponic system, you don't have that."

The leader of NASA's lunar soil research effort agrees. While certain plants do thrive in hydroponics, their support system is so complex that it's prone to fail, says Don Henninger, a soil scientist at the space agency's Johnson Space Center.

"The soil system probably requires lower degrees of monitoring and control. It's more easily managed, and, in the long run, is going to be considerably more reliable," Henninger predicts. "In a hydroponic system, changes occur very rapidly," he explains, "whereas a solid substrate medium is a whole lot more forgiving."

Henninger's group has synthesized zeolites—minerals important for photosynthesis—from simulated lunar soil. Judging from their success, he believes it can be done with the real

thing. "But we're really still back in the Model-T era," he cautions.

Easterwood and Henninger believe humans will need both kinds of CELSS. As they envision it, a small crew sent to build a lunar or Martian base wouldn't have time to till the soil they found there. But they believe a hydroponic system, by itself, wouldn't be able to feed the burgeoning population of an established colony. And, they ask, how could it possibly satisfy our appetite for home?

"We could make [a lunar garden] much more Earthlike than you could ever do with a hydroponic system, and that can be an important psychological factor with long tours of duty," Henninger says.

While making a CELSS "Earthlike" may be desirable, it certainly isn't practical, according to Knott, MacElroy and their researchers. They point to a two-and-a-half-acre CELSS project now underway in the Arizona hills as an example. Called Biosphere 2, the construction at SunSpace Ranch, in the Santa Catalina Mountains outside Tucson, resembles a big terrarium. This $4 billion ecosystem-under-glass contains plants, animals, every type of terrain imaginable, and—when it's tested in 1989—people.

"[Biosphere 2] may prove to be very important psychologically, but we [at NASA] are hoping to *limit* the ecosystem," says Knott. "We're not interested in some obscure beetle in a rain forest of the Amazon. You can eliminate some of the pieces and really develop the system in a recycling manner without building a total Earth."

Still, he admits, preventing cabin fever is important, too. As if being cooped up with the same six people for three years won't be enough, imagine how monotonous meals could become in an extraterrestrial garden limited to a handful of crops chosen because they grow fast or don't take up much room. "You can't just go down to the supermarket and pick out what you need," Knott says.

So NASA hired a nutrition consultant to come up with a "'Mother Earth News' type of kitchen list" of totally vegetarian recipes using ingredients grown in Knott's CELSS, along with the appliances and gadgets necessary to cook them. Hundreds of recipes and several sample menus were developed: the potential fare ranges from ordinary vegetable soup and English muffins to more unusual spinach tarts and soybean meatballs. None include tomatoes, an important cooking base, because tomatoes take too much time and space to grow. As a result, Knott figures, without a lot more work, only 30 or 40 of the recipes will be appetizing enough to be considered. And we won't know about that, he adds, until there's enough money to put chefs and appliances in the test kitchens now sitting empty in Hangar L.

Whether or not we leave this planet with the dirt of the Solar System under our fingernails, one of the real benefits to come from the plant growth and automation studies, says Knott, will be its spinoff potential on Earth. And all debates about methodology aside, Easterwood says there's really only one school of thought in CELSS research: "Whether you use a Rolls Royce or a Cadillac to get there, you're still going to have the road." □

Beth Dickey is a Florida-based writer and radio correspondent who specializes in space and science.

ANTIMATTER GETS SERIOUS

It's the key to our Big Front Yard. Now all we have to do is find a way to harness it.

▼ ▼ ▼

BY JOEL DAVIS

The numbers are straight out of science fiction:

A one-way trip to the Moon—nearly a quarter of a million miles away—takes only about four hours, barely enough time for an in-flight movie and dinner. Freighters and cruise ships ordinarily reach Mars orbit in just under two weeks.

In the year 2090, at a space station out near Pluto, flight teams make final checks on a robot probe bound for Nemesis, the Sun's recently discovered brown dwarf companion, which is currently about a light year away. Starfarer I will get there in six years and eight months, travelling at 15 percent of the speed of light. The first close-up pictures of Nemesis and its cometary halo will arrive at Earth a year later.

No big deal, when you have antimatter engines.

It used to be that antimatter space propulsion was discussed only by crackpots and Trekkies, but no longer: The idea of an antimatter-powered rocket may be going legitimate. A 1986 Air Force-sponsored study specifically identified antimatter as a promising future technology. A recent study by the Rand Corporation showed that it will be possible in the next few years to make and store antimatter at a cost of about $10 million per milligram. That may seem like a lot of money, but it would make antimatter engines competitive with the best current chemical space propulsion systems.

Another study, by the Brookhaven National Laboratory in New York, found that *grams* per year of antiprotons could conceivably be produced and stored at a cost of a million dollars per milligram. Said Colonel Ross Nunn, director of the Air Force Astronautics Laboratory, in a recent article in the aerospace trade magazine *Aviation Week & Space Technology:* "The 'giggle factor' (about antimatter) is over. Antimatter is real, and we know how to make it and keep it. It has promise."

Antimatter is the mirror image of ordinary matter. While a proton has positive charge, the antiproton has negative charge. Similarly, the antielectron, or positron, has a positive charge—the exact opposite of a normal electron.

Antimatter was first discovered in 1932 by Carl Anderson of the California Institute of Technology. It exists in nature, but physicists also make and store it in incredibly tiny amounts, and use it in particle accelerators to probe the innermost secrets of quarks, gluons and other exotic denizens of the

microworld.

As scientists master techniques for creating and storing antimatter in quantities billions of times larger than is done today, they also will be developing the energy source for a new space propulsion technology. And as antimatter becomes economically competitive with chemical space propulsion, it will change all the rules for space missions.

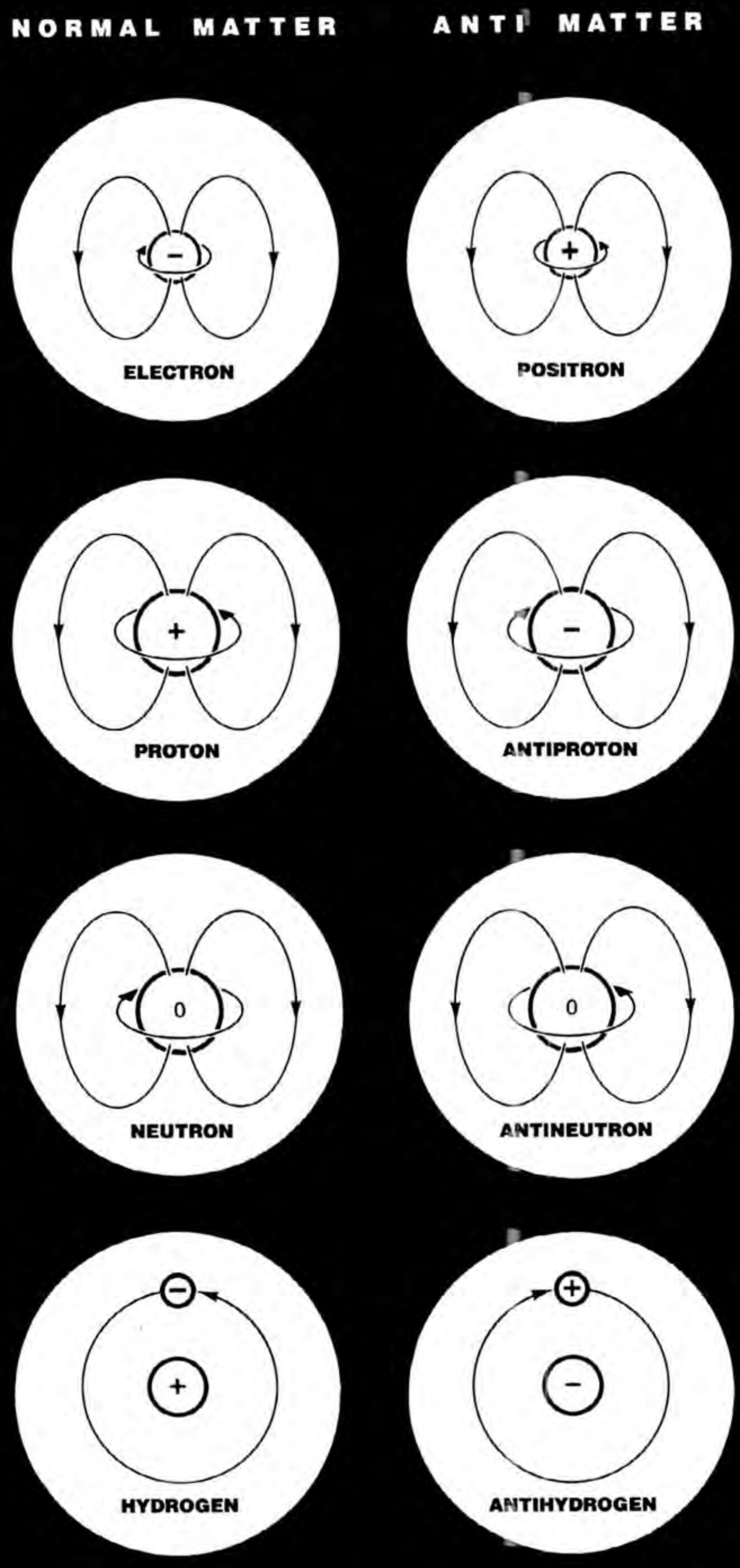
The reason for antimatter's amazing potential for space propulsion is simple and well known. Mass is equivalent to an enormous amount of energy. In a sense, mass is superconcentrated energy, whether it's in the form of matter or antimatter. When a particle of antimatter comes into contact with a particle of matter, their reversed properties "cancel out."

The result is the total annihilation of both the matter and antimatter. All the mass of both particles converts into energy. That annihilation reaction obeys Einstein's famous formula, $E = mc^2$: energy equals the mass of a particle multiplied by the square of the speed of light. Therefore, the annihilation of just one gram of matter and antimatter would produce the energy of a twenty kiloton atomic bomb. The energy contained in the space shuttle's propellant could be produced by an amount of antimatter no more massive than a sugar cube. In fact, the matter-antimatter combination is the most concentrated means of storing energy available.

The practical consequences of this will be immense for space exploration. Robot and human-crewed missions that were once considered impossible will become easy. Even more important, antimatter space propulsion could open up the Solar System to human colonization.

Designs for antimatter rocket engines exist today, but what still is needed is an economic technology for creating and trapping micrograms of the material. That's not a trivial task, and it may be many years before we're able to fly off to Mars for our vacations.

One timetable has been proposed by Major Gerald Nordley of the Air Force Astronautics Laboratory, who sees the first experiments with small antimatter-powered rocket thrusters happening at least ten years after the beginning of serious antimatter tech-



Antimatter particles are the mirror images of "normal" matter, with such fundamental properties as electrical charge and direction of spin reversed.

DATA BASE

Highlights of NASA's First Thirty Years 1958–1988

continued

1980

MAY

1973 NASA launches Skylab, America's first manned space station.

FEBRUARY

1974 The last Skylab crew wraps up 84 days in orbit, the longest U.S. spaceflight to date.

JULY

1975 American and Soviet spacefarers link up during the Apollo-Soyuz Test Project.

JULY

1976 Viking 1 makes the first controlled soft landing on the surface of Mars.

AUGUST

1977 The voyages of the test shuttle orbiter Enterprise begin with a 5½ minute glide flight.

DECEMBER

1978 The Pioneer-Venus mission rockets four probes into the planet's thick atmosphere.

MARCH

1979 Voyager 1 sends back stunning close-up images of the giant planet Jupiter and its moons.

NOVEMBER

1980 Voyager 1 takes the first detailed photos of Saturn's remarkable ring system.

APRIL

1981 John Young and Bob Crippen pilot Columbia into orbit on the space shuttle's maiden flight.

NOVEMBER

1982 "We Deliver!" The STS-5 crew deploys two satellites on the shuttle's first "operational" mission.

JUNE

1983 Sally Ride becomes the first American woman to fly in space aboard Challenger.

NOVEMBER

1984 Discovery's STS-51A crew snares two wayward communications satellites and returns them to Earth.

OCTOBER

1985 NASA launches the largest number of people–eight–to fly aboard a single spacecraft.

JANUARY

1986 Seven astronauts are killed when Challenger is destroyed 73 seconds after liftoff.

DECEMBER

1987 NASA awards work packages to build the Space Station, a permanent base of operations in the sky.

JULY

1988 Discovery moves to the launch pad for STS-26 as the shuttle returns to flight status.

1977

1975

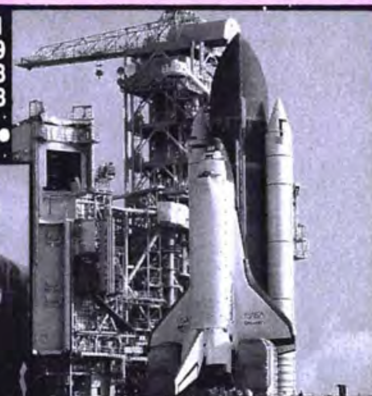
1973

1981

1984

1988

1988



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TOM USCIAK

DATA BASE

Highlights of NASA's First Thirty Years 1958—1988

1969

OCTOBER
1958 NASA officially starts operations, with T. Keith Glennan as its first Administrator.

APRIL
1959 NASA announces the names of the original seven astronauts chosen for Project Mercury.

AUGUST
1960 Echo, a Mylar balloon 100 feet wide, is placed into orbit as a communications satellite.

MAY
1961 Alan Shepard rides a Redstone rocket into space to become America's first astronaut.

FEBRUARY
1962 John Glenn circles the Earth three times in Friendship 7 during the first U.S. orbital flight.

MAY
1963 Gordon Cooper wraps up Project Mercury with a pinpoint landing after 1½ days in space.

JULY
1964 Ranger 7 sends back the first close-up pictures of the lunar surface.

JUNE
1965 Ed White takes America's first walk in space outside his Gemini 4 spacecraft.

SEPTEMBER
1966 Pete Conrad and Dick Gordon ride Gemini 11 to a new altitude record of 853 miles.

NOVEMBER
1967 The awesome Saturn 5 moon rocket lifts off on its initial test flight.

DECEMBER
1968 Apollo 8 completes ten lunar orbits during the first manned voyage around the Moon.

JULY
1969 "We came in peace for all mankind." Armstrong and Aldrin make the first human footprints on the moon.

APRIL
1970 Astronauts Lovell, Swigert and Haise return safely to Earth after an explosion disables Apollo 13.

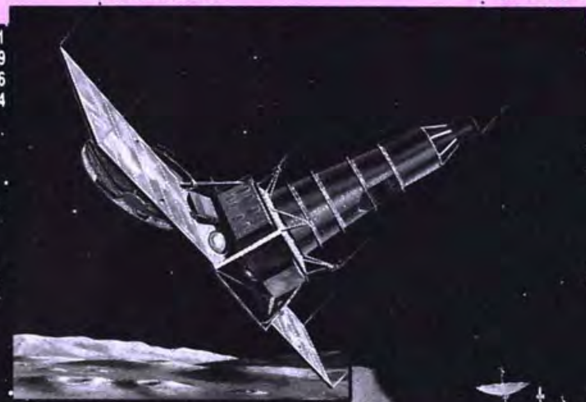
JULY
1971 The Apollo 15 crew makes the first use of the Lunar Rover moon buggy.

DECEMBER
1972 The Apollo 17 astronauts land in the Taurus-Littrow valley to complete man's first series of Moon expeditions.

1959

1962

1964



1967

1971

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nology development. Experiments with engines having hundreds of thousands of pounds of thrust might not begin until 20 years after that, and small space probes with antimatter propulsion systems would appear at that time. However, major space transportation applications using antimatter are at least 50 to 75 years in the future.

As with those "Dungeons & Dragons" fantasy quest games, there are several significant tasks that need to be carried out in order to get to the "holy grail" of antimatter space propulsion. Physicists must devise ways to create large amounts of antimatter—at least several tens of micrograms. That's about a billion times more antiprotons than are used in some current physics experiments. New breakthroughs in warm-temperature superconductors may help to make antimatter production—which requires large and expensive particle accelerators—more energy- efficient.

We also must develop methods of capturing and storing micrograms of antimatter for long periods of time, and in a very small space. Only then will antimatter be reduced from the hundreds of millions or even billions of dollars it now costs to produce a milligram.

Tomorrow's antimatter rockets will depend on the annihilation of antiprotons with normal matter. The initial byproducts of this kind of annihilation are subatomic particles called pions. Pions have mass, and can carry an electrical charge, which provides two different ways of getting thrust. First, electrically charged pions can be controlled and aimed by powerful magnetic fields. The pions themselves would make up the rocket exhaust. Secondly, the electrical charge on the pions can be used to heat a fluid and turn it into a supervaporized gas that would provide enormous thrust for the rocket.

Several designs for working antimatter rockets already exist. The simplest, which could be built using present-day technology, is the Augenstein antimatter rocket designed by Bruno Augenstein of the Rand Corporation in California. It uses a block of tungsten metal about 28 centimeters square. The tungsten block is porous, so that a fluid like liquid hydrogen or liquid methane can seep through and around it. In the middle of the block is a small hollow chamber. Running through the block from the rear is a tiny channel to carry antiprotons from a magnetic bottle. At the front end of the block is the rocket's nozzle.

When fluid percolates through the tungsten block, tiny amounts enter the hollow in the center. Antiprotons from the magnetic bottle pass through the channel to the hollow cavity, meet the liquid hydrogen, and BOOM!. Annihilation.

Energetic pions then pour out and pass through the tungsten block, heating it and the liquid hydrogen percolating through it. The liquid hydrogen comes out of the block with an exhaust velocity of 9,000 to 10,000 meters per second. Such a rocket could produce up to 100,000 pounds of thrust.

Its fuel efficiency also would be two and a half times better than the liquid hydrogen/oxygen propulsion system of the Space Shuttle's main engines, and four times better than the best solid fuel rockets. A rocket booster using this first-generation antimatter rocket could put up to 20 percent of its gross liftoff weight into orbit. Today's best boosters can orbit no more than two percent. An antimatter-powered vehicle the size and mass of a Boeing 747 could put a space shuttle payload into low Earth orbit.

Engineering an Augenstein antimatter rocket is not beyond us today. Some techniques already used for chemical rockets could be adapted to its use. The "working" fluid, for example, could first flow through part of the rocket nozzle to cool it. Also, the entire tungsten block engine could be incorporated into the NERVA nuclear rocket design that dates back to the 1960s. Stephen Howe of the Los Alamos National Laboratory has been toying with just such a version of Augenstein's engine. From the bottom of the nozzle to the bottom of the propellant tank, the Augenstein/Howe antimatter rocket is about four and a half meters long. The nozzle would be about one and a third meters wide.

Other antimatter rocket designs are more advanced. One, proposed by David Morgan of the Lawrence Livermore National Laboratory, would use the annihilation products themselves as the exhaust. It would be about three meters long, and the wide end of the exhaust nozzle would be about two meters wide. For fuel, it would use antiprotons and neutral hydrogen atoms. The engine itself would be wrapped with powerful superconducting magnetic coils.

In Morgan's design, a beam of antiprotons ten centimeters wide streams down into the narrow neck of the rocket engine. A second beam, made of neutral hydrogen atoms, is injected into the annihilation area from the side. When the two beams meet, the result is total annihilation, and a violent spray of pions and gamma rays pours out. The powerful magnetic fields from the superconducting magnets force the charged pions to go flying out the back of the nozzle, producing exhaust.

The Morgan antimatter rocket is truly far out, and the exhaust velocity is mind-boggling: 282 million meters per second, or 94 percent the speed of light! It could produce several times as much thrust as the Augenstein propulsion system, and have far greater efficiencies. Current ion propulsion systems are as fuel-efficient, but offer only a few tenths of a pound of thrust.

The implications of a working Morgan antimatter propulsion system are staggering. Simply put, any space mission you could think up, you could carry out.

The Augenstein propulsion system could be built now, and is a likely design for the first generation of antimatter rockets; once we can economically make and store milligrams of antimatter, it will certainly become a reality. A hundred years or more from now, orbiting antimatter factories may be commonplace. Antimatter will be routinely stored and used by the kilogram. Even the more exotic Morgan rockets will be as accepted as a "slant six" automobile engine is today. And when that happens, antimatter will open the Solar System to humanity the way the railroad opened the American west.

Example: In the year 2006, an antimatter-powered rocket probe is launched to Pluto, nearly three billion miles from Earth. The probe accelerates at 9.8 meters per second per second, or one G of acceleration. Suppose it accelerates at this rate for 1.46 billion miles, flips over, and decelerates at the same rate the rest of the distance. It would arrive at Pluto in just 16 days.

Does constant one-G acceleration sound too outrageous, even for antimatter propulsion? Let's make it one-tenth of a G, or 0.98 meters per second squared. At that acceleration, the antimatter-powered probe gets to Pluto in about 50 days.

Now let's bring it closer to home. An antimatter-powered shuttle leaves Earth orbit and heads for the Moon, some 250,000 miles distant. Accelerating at two Gs for just one hour, it would pass by the Moon in about three hours!

With antimatter, the "X-Wing" fighters from the "Star Wars" movies will no longer be celluloid fantasies. Antimatter-powered spaceplanes will be able to perform fighter-like maneuvers in orbit. They will be able to reverse directions, make 90-degree turns in space, "dogfight," and then turn around and come back to base. Those kinds of maneuvers are utterly impossible with any other kind of space propulsion system, which may explain why the Air Force is interested in antimatter for

continued on page 62

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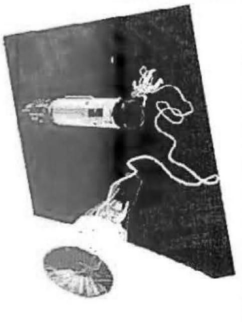

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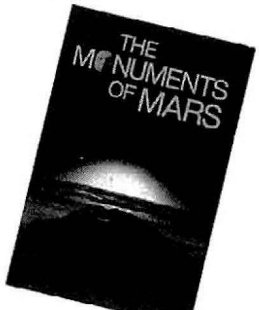

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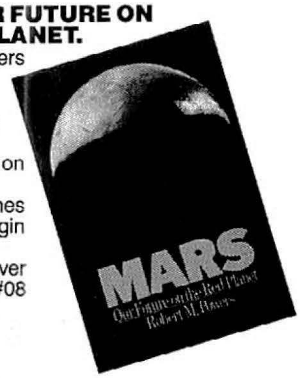

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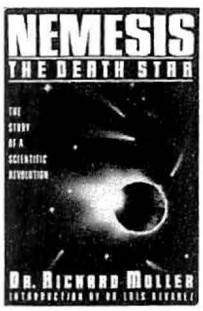

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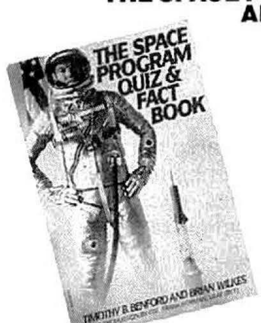

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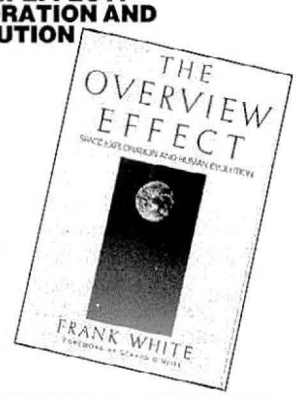

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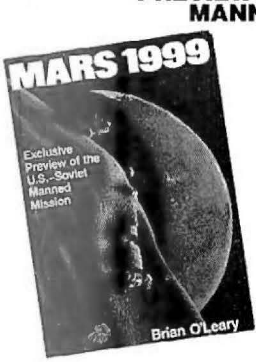

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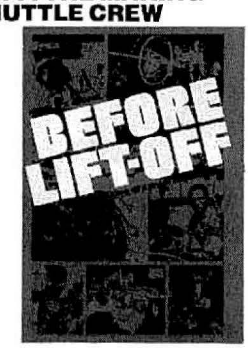

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EARTHLY PURSUITS

A Spinoff Hall of Fame

And the winners are...

▼ ▼ ▼

By Gary R. Graf

A piece of the Viking robots that explored Mars' surface is helping to free diabetics from the unpleasant daily regimen of insulin syringes. In San Diego, a method for recycling waste water in a space station or lunar colony is proving its worth as a means of treating sewage.

These two space "spinoffs" were given special recognition by NASA recently, when they were inducted along with three other bright, commercially-applied ideas into the U.S. Space Foundation's newly created Space Technology Hall of Fame. The awards also marked the 25th anniversary of NASA's Technology Utilization Program that promotes space spinoffs.

These ubiquitous byproducts of the nation's space program range from cordless tools and scratch-resistant plastic sunglasses to pyro-ceramic cookware and freeze-dried backpacking food. The five spinoffs were selected for the Hall of Fame from hundreds of gee-whiz space technologies that have found commercial acceptance in the home and in the workplace.

One of the first inductees is Donald S. Friedman of NASA's Goddard Space Flight Center, selected for his Martian insulin supply device. The tiny pump and valve system, controlled by a microprocessor, was originally developed for the Viking Mars Lander. Today it's called a Programmable Implantable Medication System, or PIMS.

About the size of a woman's compact, the PIMS provides diabetics with automatic insulin doses regulated to the patient's need. About 12,000 diabetics now lead more normal lifestyles because of the PIMS.

In San Diego and several other communities, water hyacinths have been thriving on the mineral and organic crud in city waste water ponds. Aesthetics aside, the verdant "aquaculture" is being used to recover drinking water from sewage.

The spinoff was developed by Dr. Bill Wolverton of NASA's Stennis Space Center (formerly the National Space Technology Laboratories) in Mississippi as a possible way to recycle precious water for extraterrestrial missions or colonies. A million-gallon-per-day facility proved so cost-effective that San Diego is building an even larger hyacinth/sewage treatment plant.

From the Moon to Manhattan, Apollo space suit breathing apparatus has helped to keep people alive. The need for a lightweight, portable life support system on the Moon is obvious, but its value is just as clear to firefighters who risk inhalation injuries from the fumes of burning plastics, exotic chemicals and other synthetics used in homes and businesses.


NASA

Lightweight equipment for firefighters, derived from Apollo spacesuit technology.

A four-year development program involving NASA, the U.S. Fire Administration, fire chiefs and firefighters' groups used Apollo technology to replace a cumbersome air tank and mask system that hadn't changed since the 1940's. Firemen often chose to breathe smoke rather than strap on the heavy gear. Too many paid a dear price for that choice.

"When you wore that thing for 15 minutes, you couldn't wait to get out of it," New York City Battalion Fire Chief James Manahan said. The lighter, more compact and comfortable system derived from space technology, he said, "was a major improvement in firefighting equipment, no question."

The Space Foundation also selected an energy-saving mechanism that automatically adjusts voltage in electric motors according to the load on the motor. The Power Factor Controller was initially developed by Frank Bola at NASA's Marshall Space Flight Center, and today is licensed to hundreds of motor control manufacturers.

A variation of the device has all but eliminated the risk of dialysis and other critical hospital machines shutting down due to power surges when emergency generators are in use. The controller extends motor life and reduces maintenance, while reducing power requirements by as much as 65 percent on idling motors. Given the millions of electric motors that move our mechanized society, the controller is making no idle contribution.

In the late 1960's, Thomas G. Bulter at Goddard Space Flight Center developed computer software that would automate the time- consuming mathematical process of spacecraft structural analysis. Today, hundreds of industrial firms are using his NASTRAN software to analyze and solve problems in automotive, aircraft, refinery, locomotive and architectural design.

These first Hall of Fame inductees were selected by a panel of space industry experts and congressional leaders. The awards honor the technologies, the individuals who developed them and the private industries that made the spinoffs publicly available. Eventually, the borrowed space hardware will reside in a new museum that the U.S. Space Foundation is designing with help from the Smithsonian Institution. The Hall of Fame will be on the foundation's campus in Colorado Springs.

The foundation's executive director, Dick MacLeod, expects the Hall of Fame to stimulate and exploit space technologies and to generate support for space programs.

"Few people realize that much of what we take for granted in everyday convenience is the direct result of space technology," he said. □

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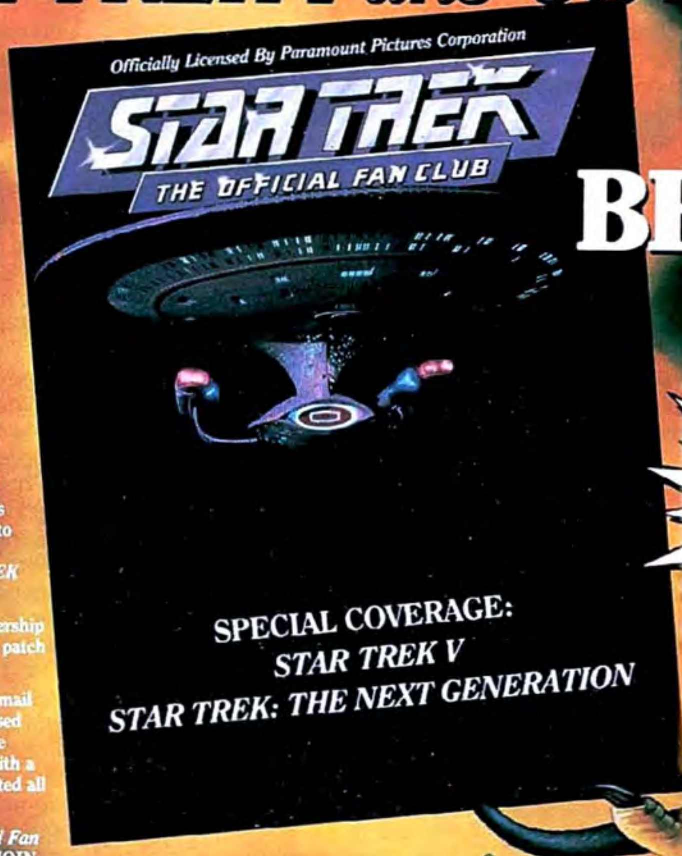

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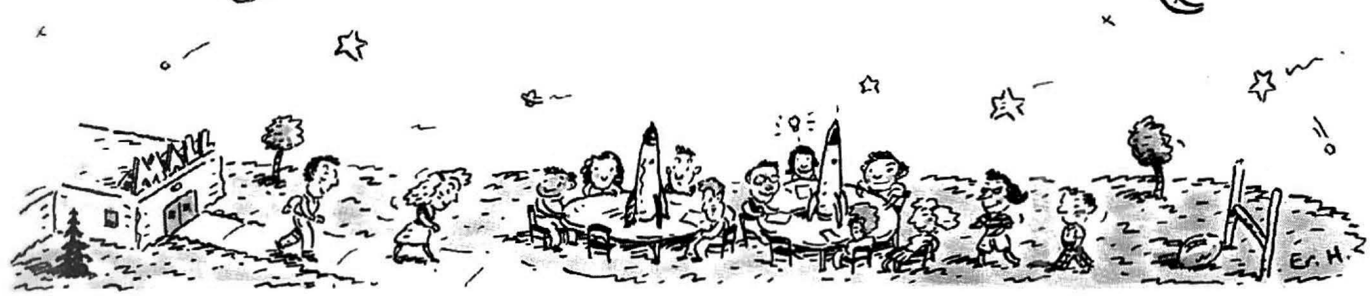
SPACEFARERS

Rockdonnel, Vulture and Grumbo



ERIC HANSON

Learning about space business the fun way.

▼ ▼ ▼

By Norman Sklarewitz

On most sunny weekends, Tracy McCloud, 16, of Canyon Country, Calif. is busy with her Canoga High School friends seeing a movie or, if she has the money, shopping. And Garret Messner, 17, of Thousand Oaks, plays football or hits the beach with his buddies.

But the weekend of April 23-24 was a bit different for these two young people, who along with dozens of other California teenagers, converged on NASA's Jet Propulsion Laboratory in Pasadena for "SpaceSet '88," an exercise that introduced the participants to space exploration in a realistic, hands-on setting.

SpaceSet '88 was organized by the Explorer Scouts' Space Exploration Post 509, which JPL sponsors. Attendance was open to anyone between ages 15 and 20. Most of the teens were from the metropolitan Los Angeles area, but several made the trek all the way from San Jose, 400-plus miles from Pasadena.

From Friday evening almost nonstop through Sunday afternoon, the teens were challenged to project themselves into the future as senior project directors, space scientists and engineers. Their task: To design workable plans for a 21st century colony on the planet Mars.

SpaceSet sounds like the kind of program that would attract mainly the class nerds. It wasn't at all; the gathering included a liberal sprinkling of students sporting athletic letter sweaters, plus clothes and hair styles reflecting all the current teen age fads. "They were all just normal kids," says 19 year-old post chairman James Snelling.

The cost for the weekend program was $45, which covered meals and incidentals. Attendees also brought their own sleeping bags; overnight accommodations were on a gym floor at a nearby high school. And lest anyone get any ideas, Jon Hawkins, 19, the program's director of operations, set the ground rules for how the young people were expected to behave. "You're a professional now," he told them.

The premise for SpaceSet was the announcement in April 2020 by a futuristic group called the "Foundation Society" of its intent to construct the first human settlement on Mars. Four mythical companies—"Rockdonnel," "Grumbo Aerospace," "SVK" and the aptly named "Vulture Aviation"—decided to compete for the lucrative contract, and had to prepare comprehensive proposals to build and run the colony.

The 68 students attending SpaceSet '88 were divided up among the corporations. An adult served as chief executive officer of each company—but only as an advisor. The CEOs took no part in the proposal preparations.

Each group of student executives was also given something of a corporate persona on which to draw. SVK, for example, was supposedly founded by Luke Skywalker, Darth Vader and Ben Kenobi (since retired, but still there in, uh, spirit). Vulture was an aircraft manufacturer facing shrinking sales, and almost desperate to break into the new market represented by the Mars settlement contract.

At 8 o'clock Saturday morning, the corporate staffs huddled to begin planning their strategies. JPL provided each company with a conference room equipped with a personal computer, copier, viewgraph materials, marking pencils and simple drafting instruments. Reference materials, which could be checked out for no more than 30 minutes, also were available.

Intended as a learning experience, SpaceSet '88 also was a lot of fun as the exuberant young people became caught up in the competition to win the contract. They faced a multitude of difficult questions that will confront real-life Mars planners in the next century: what safe but economical power sources should be used? How about coping with the dust storms and winds that sweep Mars? Can the settlement be economically self-supporting? (Undoubtedly reflecting the interest of typical teens, two proposals contained provisions for shopping centers, appropriately dubbed Mars Malls.)

The groups met throughout Saturday and into the predawn hours of Sunday morning. "It was more intense than anything I ever expected. I was amazed how many good ideas were floating around and how little was getting accomplished," says Vulture Aviation's Doug Dearing, 18. "It didn't seem that we would ever complete the project. But then it all came together."

Eighteen year-old Tanya Zimmerli, a student of electrical engineering and computer sciences at UC-Berkeley, perceived something that younger participants may have overlooked. "This was a management experience. It was all about organization," she said. "It turned out to be a business simulation."

Which is precisely what the competition is *really* about, according to Rob Kolstad, who originally conceived SpaceSet with two other members of the Explorer Scouts' National Science and Engineering Committee. "We don't tell the kids that, of course," he smiles.

The competition was judged by Anita Gale and Richard Edward, the other founders of SpaceSet, along with five other engineering and education professionals. And the winner? With that name, how could they lose? Vulture Aviation. □

BOUNDARIES

The Star Most Likely To

...have planets, that is. Maybe.

▼ ▼ ▼

By Tony Reichhardt

I want a new world. I'm tired of Mars. We've seen Saturn and Jupiter. Pluto is a joke. I want someplace *else*.

And don't tell me how it's possible to detect planets around other stars based on gravitational wobbles. Or how certain suns have something called "circumstellar disks," which are probably just so much dust anyway.

What I want is another *planet,* not smoke rings. Someplace with a sky, and mountains. I want something just like Earth. Except without Dr. Ruth.

These are the kinds of thoughts that run through my head as I sit listening to paper after paper at a recent symposium on "The Formation and Evolution of Planetary Systems," held at the Space Telescope Science Institute in Baltimore.

One by one, the astronomers troop up to the podium to give their talks. "L134N: A Protostellar Dark Cloud." "Ring Formation Around Rapidly Rotating Objects." Yeah, yeah, yeah. Where the hell are the *planets?* Everyone suspects that the universe is teeming with them. Find one!

"Low-Mass Star Formation in the Contaminated Gum Nebula." "Beta Pictoris: Did Planets Form?"

Sorry, what was that about planets?

And then another paper, called "CCD Observations of the Beta Pictoris Disk," by Richard Terrile of NASA's Jet Propulsion Laboratory. And suddenly I'm sitting up, taking notes.

Terrile and Bradford Smith of the University of Arizona were the first to photograph, in 1984, a curious object that had appeared unusually bright in an infrared map of the sky taken by the orbiting Infrared Astronomy Satellite. Their visible-light photo showed a southern hemisphere star, Beta Pictoris, surrounded by a thin but substantial disk of material. At the time, press reports talked about the discovery of a new solar system.

But Smith and Terrile had found no planets. All anyone could say for sure is that there was a lot of solid material circling around this young star, and that it was probably more than just dust particles. "Rocks, bricks and larger," is how Terrile describes the dark stuff orbiting around Beta Pictoris.

Then in February 1985, and again around Christmas 1986, Smith and Terrile took advanced charged-couple-device (CCD) sensors to the Las Campanas observatory in Chile, for a clearer look at the star astronomers call "Beta Pic."

NASA

"Beta Pic" (center, with its light blocked artificially) and the mysterious disc.

What they got were the best pictures yet of the object Terrile says is "the prime candidate out there" for being an honest-to-goodness solar system. Before I get excited enough to rush out and tell someone, however, I hear Terrile's flat disclaimer: "We have found no direct evidence for planets."

Sulking, I decide to listen anyway. What Smith and Terrile *do* see in their spectacularly clear images is that the disk is approximately twice as wide as it appeared in earlier photos. They also find—based on the reflectivity of the particles and the way they polarize light—even stronger evidence that the region near the star appears to be empty, somehow swept clean of material. And that's where things get interesting.

Current theory holds that solar systems condense from swirling disks of dust and gas. Large particles in the disk "accrete" into planets, moons and such, so that what you eventually get—and what our Solar System indeed has become—is a group of planets orbiting in more or less empty space around a star. Nice places to live, but very difficult to see from afar, being tiny spots in the vast darkness.

Astronomers also believe that a diffuse ring of "proto-comets" lies at a great distance from our own Sun—the so-called Oort Cloud. A second cloud has been proposed to lie just outside the orbit of Neptune, and Smith and Terrile think that what they see around Beta Pictoris may be an analog to this "inner Oort Cloud," perhaps at an earlier stage of development.

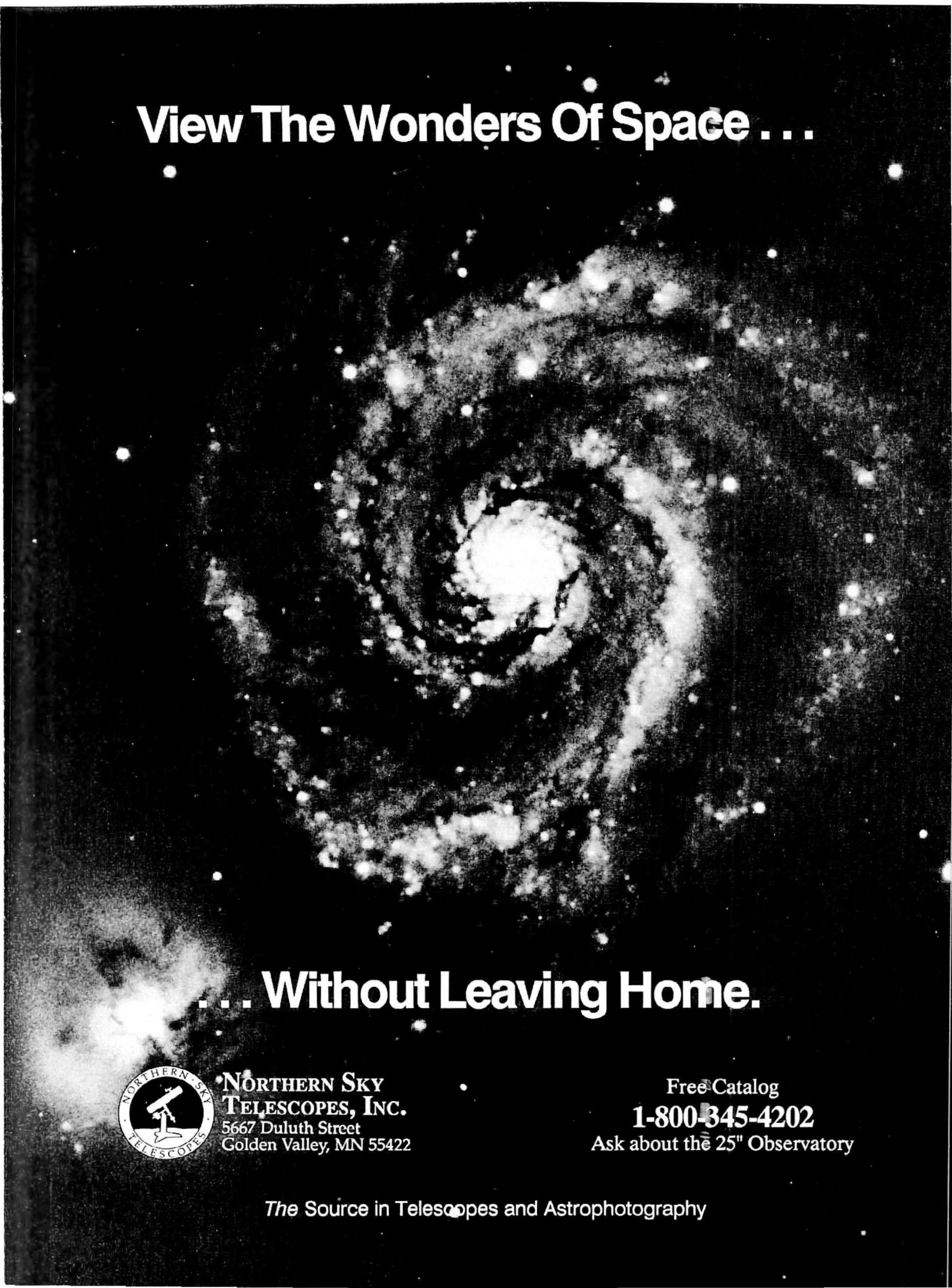
As to what swept the center of the disk clean, couldn't it be—just *maybe*—that planets have already accreted and gobbled up whatever particles were there? Terrile is cautious:

"[Beta Pictoris] could have a fully formed solar system like our own, surrounded by a remnant disk, which is visible. It's also conceivable that Beta Pic is young enough *not* to have full-fledged planets."

He points out that we know little about planetary formation, but that it seems to happen very early—good news, considering that Beta Pic is only one percent or less the age of our Sun. And Terrile is very interested in recent French spectral data suggesting that kilometer-sized objects may be falling inward toward the star (kilometers! comet-size! almost *planets!).*

So he and Smith intend to continue studying Beta Pictoris, improving their observations, trying to pin down the exact size and distribution of the Stuff That Would Be Planets. And they're investigating other disked stars, as well: Fomalhaut, Vega, something called Alpha PSA.

Boy, do I wish them luck. □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REVIEWS

Liftoff.
The Story of America's Adventure in Space.
By Michael Collins
Grove Press.
320 pages. $25.00.

By Tony Reichhardt

Fans of Michael Collins' first book have waited a long time for a sequel. Happily, the wait was worth it.

Carrying the Fire, published five years after Collins' historic Apollo 11 voyage to the Moon, had everything: drama, plenty of anecdotes, and the first-hand authority of someone who'd actually lived the story. It was even written well, and with no ghostwriter sharing the credit. Only Tom Wolfe has produced as good a book about the American space program.

Now, 14 years later, comes *Liftoff.* Collins has turned a potentially dull subject–the origin and evolution of space machinery–into a lively and entertaining read. In his first literary outing, the former astronaut gave us a personal account of his own experiences, from test pilot to NASA employee and then back to private citizen. This time, he's as interested in the machines–and the people who built them–as he is in the astronauts.

And so we're introduced to legendary figures like Max Faget, the man who designed the Mercury capsule (today Faget heads a company trying to build a private space factory in orbit). Back in the '50s, Faget and other tough-minded engineers tackled the most basic problems of spaceflight for the first time. They were the pioneers who had to figure out, from scratch, what shape a space "capsule" should be, and how you return astronauts to Earth, and whether you should include an escape system or not.

Collins explains these issues, and the machines themselves, with an easy grace–maybe because, as he tells us, he isn't much of a mechanic himself, and so approaches technology from a user's perspective rather than an engineer's. He describes a row of Gemini spacecraft hidden by scaffolding in a McDonnell Aircraft plant as looking like "asparagus spears peeking up through a dense tangle of weeds. They were most noticeable not by shape but by their dull black color....They were serious machines, dormant now, but with a hint of power and speed in them. They looked strong."

Mike Collins prior to his Gemini 10 flight in 1966 (left) and on the way to the Moon in 1969.

The disappointing news about *Liftoff*, at least for those who've read Collins' first book, is that the accounts of his own space missions–Gemini 10 and Apollo 11–are repeated here almost verbatim. *Liftoff* opens with Apollo 11's voyage, and within a few pages I had a strong sense of déja vu. Anyone who hasn't read *Carrying the Fire*, though, should find the first-hand narratives fascinating.

Perhaps Collins repeated himself in these sections because he'd said everything the way he wanted to the first time. It isn't that he's lazy, because in later chapters he's managed to dig up plenty of new anecdotes from the engineers and astronauts, some as long as 25 years after their missions took place.

We learn how Jim Lovell and Frank Borman, on their long- duration Gemini 7 flight in 1965, had to share a single toothbrush after one got lost. And how windows were included on the Skylab space station of the 1970s at the suggestion of Raymond Loewy, an industrial designer who had created the 1953 Studebaker. And how Pete Conrad claims to have succeeded at the difficult game of floating from one end of the cavernous Skylab to the other without ever touching the walls (to which claim his crewmate Joe Kerwin responds "Bullshit!").

Collins knows a good story, and a good quote. Jack Lousma describes a spacewalk outside the Skylab: "It's like being on the front end of a locomotive as it's going down the track. But there's no noise, no vibration; everything's silent and motionless....hanging by your feet as you plunge into darkness, when you can't see your hands in front of your face–you see nothing but flashing thunderstorms and stars–that's one of the minutes I'd like to recapture and remember forever."

When Collins turns to a discussion of NASA after the shuttle accident, he is neither judgmental nor shy about pointing out the system's faults. Like others who worked in the early space program, he wonders "how we fell so far, so fast." But he also emphasizes that spaceflight is an inherently risky business, and that we need to keep reaching for ambitious goals, with no guarantee of safety or success.

Give this book to someone who doesn't already know a lot about the space program, but would like to learn. Collins (who modestly says that he feels less kinship with his Apollo 11 crewmates than with "the scores of equally qualified astronauts and the millions of people everywhere who would have gone in my place") is a good guide and a pleasant companion. You can trust him to tell it like it was, like it is, and like it may be yet. □

Space Politics

(continued from page 22)

over government policy. One example of its nefarious influence will suffice: the squelching of the cheap and technically simple Big Dumb Booster concept by NASA and industrial firms interested in keeping spaceflight elaborate and expensive.

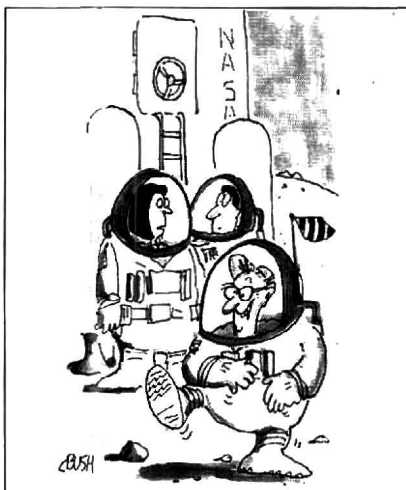
In sum, the people who now control U.S. space policy don't want to break the patterns that have led us to our current frustrations. The Iron Triangle would surely cheer any politician who called for doubling the budget while leaving the present structure intact. But such a program would only pour more billions into a national space establishment that, in the words of an Office of Technology Assessment report, has made surprisingly little progress in developing new technologies over the past quarter century. And even such a call for "more of the same" in space, according to the "Let's..." mentality, cannot attract the candidates of 1988. Why should Bush push space? It would invite scathing criticism of the space blunders of the Reagan Administration and give Jesse Jackson a bully stick to wield against the "corporate" Republicans. Why should Dukakis push space? It would invite scornful accusations that he isn't interested in reducing the deficit and is recycling, as "new ideas," the fanciful reveries of Governor Moonbeam.

So how can the United States again become the leader in space technology it once was and, given our GNP, ought to be? Only by recovering the will to do so. How can we recover the will? By sharply reducing the cost per pound of launching people and material into orbit. The shuttle was supposed to do that, but it flopped—not because of the explosion, but because of its bottom line numbers. So how do we get away from reliance on the shuttle? Not by making minor adjustments in personnel, building an unmanned shuttle-derived booster, or by vapid pronouncements like "leadership is a process." The U.S. space program will again lead the world only when we remember that institutions create nothing—at best they can only help people to create. So we must start by purging (figuratively) our space institutions of all those people who stifle creativity and perpetuate the waste of billions.

We must then encourage the young minds of America to get to work on real solutions to the space launch problem. Where are those minds to be found? First, in the universities, space clubs and wildcatting space firms around the country, where they wait and hope for government policies that won't frustrate their inventiveness. What we need now are young Wernher von Brauns working for pencil-money in makeshift labs, because they have a dream, not a job or contract, to protect.

The other potential source for new ideas is, pardon my saying so, the military. Where NASA and the aerospace industry have no incentive, no market discipline, to force them out of existing dependence on our tax dollars, the military at least has to respect the "bottom line" of national security. Of course, the Pentagon also is part of the Iron Triangle, but it retains a measure of clout and independence that enables it to pursue new technologies behind the scenes. For instance, if we ever get serious about deploying anti-ballistic systems in space, the Air Force is going to need a mammoth launch capacity. Whether it means turning to low-tech Big Dumb Boosters, or high-tech aerospace planes or laser rockets, the military will have to do it themselves—or give up on SDI.

I hesitate to conclude with an analogy to the global imperialism of the 19th century, but it is historically valid. From 1783 to 1882 the states of Europe tended to eschew far-flung colonial conquests because they were simply perceived as not worth the cost. The



I'm worried about the effect zero gravity is having on Caruthers.

only major exception, British India, was subdued by private enterprise—the East India Company. Suddenly, in the 1880s, the Great Powers leapt into overseas conquest and partitioned Africa, Asia and the Pacific. Historians ever since have argued over the motives for this surprising outburst.

Finally, in a book called *The Tools of Empire*, Daniel Headrick explored the means. He reminded us that the industrial states had, by the 1880s, acquired the steamship, the telegraph, the machine gun, quinine and other technologies that made conquest and occupation of tropical realms extremely cheap in terms of men and money. Thirty years earlier, European publics had invented many reasons, both selfish and altruistic, for why imperialism was bad. But once the technology for empire-on-the-cheap arrived, the same publics invented many reasons, both selfish and altruistic, for why imperialism was a great idea. Once the means for cheap spaceflight are available, citizens, Congressmen and Presidential candidates will likewise wake up and say, "Why not?" when you say, "Let's..." □

Walter McDougall is Professor of History at the University of California at Berkeley, and author of ...the Heavens and the Earth: A Political History of the Space Age, *which won the Pulitzer Prize for history in 1986.*

Rollercoaster

(continued from page 26)

the hangar and roll to a stop, we feel both regret and relief. On prior flights, only three of Cohen and Welch's 20 experimental subjects got really sick. Of the five of us in the Learjet, only one walks away looking truly green. Still, even Jim Martin says he avoids amusement park rollercoaster rides, and chances are we'll both avoid "The Edge" at the local park for a long time to come.

As you walk away from the plane, your fingers curl around an insignificant piece of styrofoam in your pocket. A trophy caught on the other side of the looking glass, it will find an honored spot on your cluttered desk. Taking a glance back at the now silent plane, you know that somehow the everyday world of freeways and deadlines is going to seem just a little pedestrian from now on. □

Freelance science writers Ray Spangenburg and Diane Moser are beginning to lose their greenish cast, and their appetites are coming back.

Antimatter
(continued from page 48)

space propulsion.

Scientific exploration of the Solar System also would benefit from antimatter propulsion. Robot probes could be dropped into the Sun without first having to send them out to Jupiter to receive gravity boosts. We would be able to send a probe to the rings of Saturn to scoop up ring material and then return the samples to Earth. Total mission time: a couple of years.

And human travel? Of course. Exploration teams travelling at a constant acceleration of just two tenths of a G would travel to Mars in a few months instead of nearly a year. Massive supply ships would routinely provide Martian bases with all the comforts of home. We would explore the orange atmosphere of Saturn's moon Titan, and it would take crews perhaps a year or two to get there. Further out, beckoning, will be Uranus, and Neptune, and distant Pluto.

Many years ago, the late science fiction writer Clifford Simak wrote a story called "The Big Front Yard." It was about alternate universes, and a man who walked out his front door to another Earth—the big front yard of the story. Antimatter space propulsion systems are going to be developed someday, barring some disaster or our own self-destruction. And when that happens, the Solar System will no longer be a huge and unfriendly place with distant planets and moons.

It will be our big front yard. □

Joel Davis is the author, with Robert Forward, of Mirror Matter: Pioneering Antimatter Physics, *published this year by John Wiley and Sons.*

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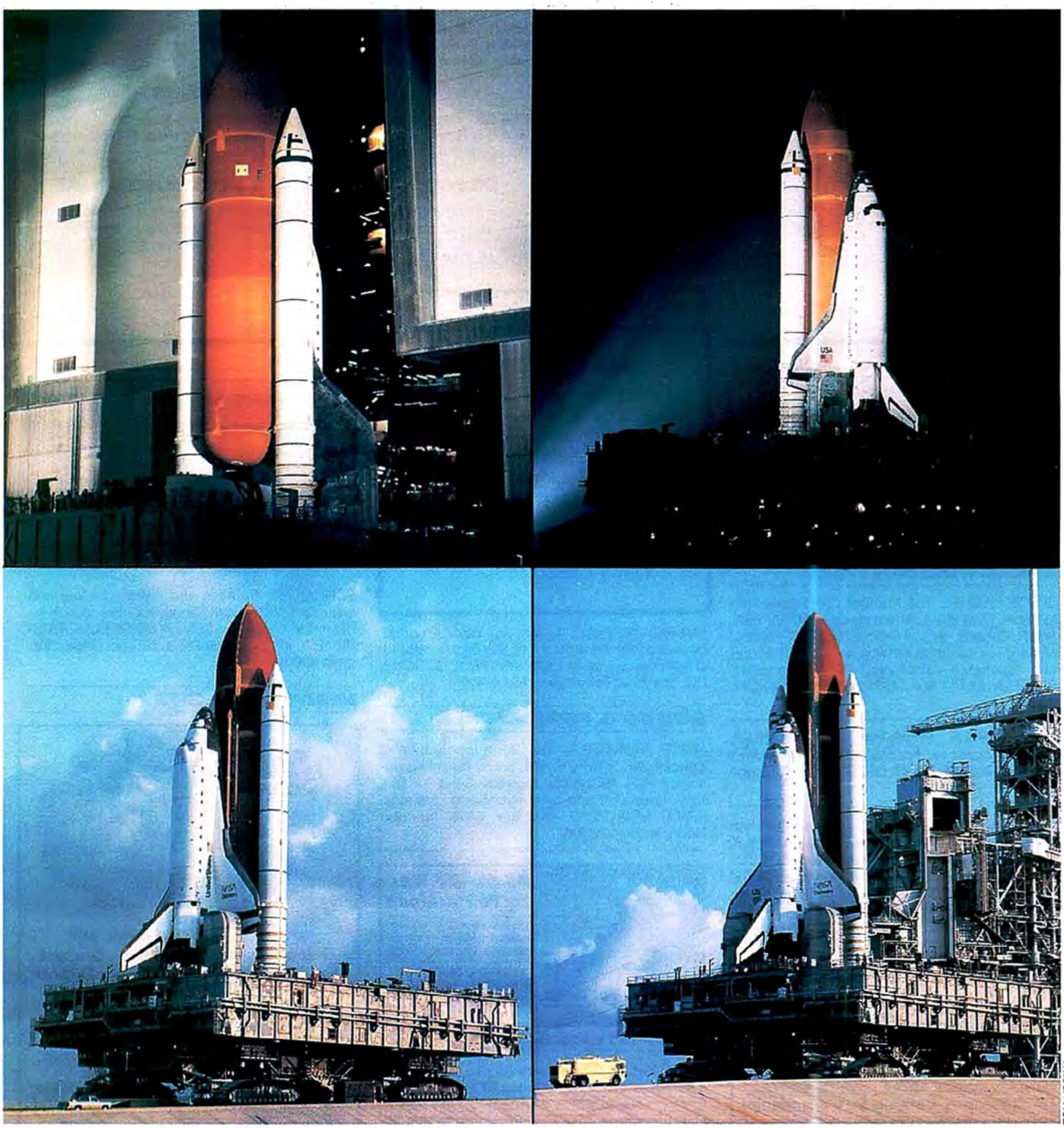

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